The Mysore Coffee Experiment Station—Bulletin No. 9.

DEPARTMENT OF AGRICULTURE

MYSORE STATE

SPRAYING OF COFFEE IN SOUTH INDIA

IMPERIAL ENTOMOLOGICAL INSTITUTE
27 NOV. 1933

BY

W. WILSON MAYNE, B.Sc.,

Coffee Scientific Officer to the United Planters' Association, South India

M. J. NARASIMHAN, B.A.,

Mycologist, Department of Agriculture in Mysore

AND

K. H. SREENIVASAN, M.A., B.Sc., (Edin.)

Assistant Director of Agriculture, Chikmagalur.

BANGALORE:

PRINTED AT THE GOVERNMENT PRESS

1933

The Mysore Coffee Experiment Station—Bulletin No. 9.

DEPARTMENT OF AGRICULTURE

MYSORE STATE

SPRAYING OF COFFEE IN SOUTH INDIA

BY

W. WILSON MAYNE, B.Sc.,

Coffee Scientific Officer to the United Planters' Association, South India

M. J. NARASIMHAN, B.A.,

Mycologist, Department of Agriculture in Mysore

AND

K. H. SREENIVASAN, M.A., B.Sc., (Edin.)

Assistant Director of Agriculture, Chikmagalur.

BANGALORE:

PRINTED AT THE GOVERNMENT PRESS

1933

FOREWORD

A bulletin on the spraying of coffee is long overdue, for, the interest in this method of increasing coffee yields has grown with astonishing rapidity during the past four years. To give some idea of this growth, I need only point out that whereas the estimated area of coffee sprayed in Mysore in 1929 was only 300 acres, an estimate made during the present year shows a sprayed area of from 18,000 to 20,000 acres. If we include sprayed areas outside Mysore, I think it is safe to state that at least 25,000 acres of coffee were sprayed in South India during the pre-monsoon season of 1933.

There are still many coffee planters who doubt the profitability of spraying but their number is decreasing from year to year. It is true that the profitability of spraying varies from district to district and there are probably estates and areas where the value of increased crop will not greatly exceed the cost of spraying. However, I believe that these areas are very few in number and restricted in size. For the great majority of coffee planters in South India spraying would be decidedly profitable and in fact it may prove to be the only means of economic salvation in a period of low prices, such as, the one through which we are passing.

If we turn to the bulletin here presented, coffee planters will, I trust, find the answers to many of the questions that have arisen in their minds in regard to spraying. The bulletin is, as will be seen, the result of team work. The title page gives the names of those scientific workers who have been directly responsible for the preparation of the bulletin but many more have had to do with the gathering of the material. Mention should be made of Mr. G. P. Krishna Iyengar of the Chemical Section, who has carried out all the analyses connected with experiments on the adhesion of Bordeaux to leaves, and of Mr. N. S. Venkatakrishniah of the Mycological Section, who has helped us in our work on spray mixtures and of the many coffee planters, who have furnished us with advice and information during the

preparation of the bulletin. Our special thanks are due to Mrs. D. Sakamma, Messrs. E. H. Young, G. S. Hameed, R. O. Oliver, R. C. Morris, Capt. E. H. A. Travers-Drapes and Mr. C. Vernede for their valuable co-operation.

This bulletin obviously does not present the final word on the spraying of coffee. In fact, I might say that we are but at the beginning of our investigations. It seems highly probable that very considerable improvements will be made on fungicidal mixtures for coffee. However, investigation on fungicides has proceeded much farther than that of spraying machinery. Our investigations in this direction labour under a severe handicap. We are far removed from our sources of supply so that alterations, which tests in the field show to be necessary or desirable, can be introduced and tested only after a long interval of time. Further, the number of types of spraying machinery which we can test is severely restricted by lack of funds, for, the number of manufacturers who are prepared to send out spraying outfits free of charge for testing on our Coffee Experimental Station is limited. Even here, however, progress is being made for, within the past year two new types of motor sprayers have been imported for test, while, one of the authors, Mr. K. H. Sreenivasan, has introduced an attachment to the D. S. P. Headland sprayer which promises greatly to increase its capacity. As a conclusion to this introduction, I should like to urge planters who are interested in spraying to keep us informed of any new types of spraying machinery which have been tried by them or in fact of any improvements, either in machinery or spray mixture, which they consider should be tested on the Coffee Experimental Station.

BANGALORE,
August 1933.

LESLIE C. COLEMAN.

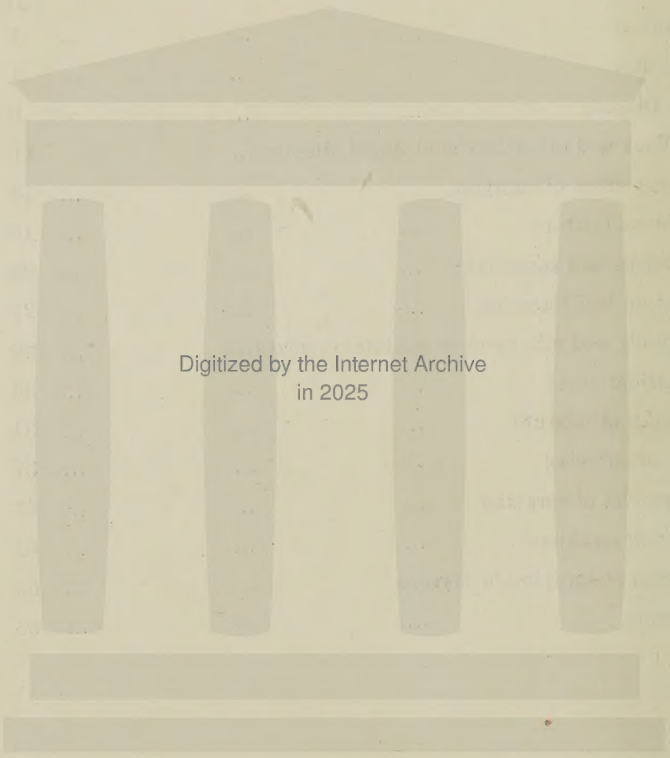
ERRATA.

The Mysore Coffee Experiment Station-Bulletin No. 9.

Page	*Line*	*For*	*Read*
3	23	(35)	(36)
12	5 of Table 2	17 7	17·7
19	2	preparations	preparation
20	6 from bottom	Pickering	Duke of Bedford and Pickering.
21	10 from bottom	investigation	investigators
29	last line	result	results
32	6	cost	costs
32	7	a full strength mixture.	full strength mixtures.
33	11	is	are
33	7 from bottom	Verminite	Vermorite
34	11 from bottom	(22)	(23)
35	4	line of application	time of application
40	2 of Table 11 under Sept. 1932.	6 61	6·61
44	2 from bottom	shows	show
46	1	*Date*	*Data*
48	1 of para 3	1922-23	1922-23 to 1927-28
51	4 of para 3	Block	Black
55	8	lines hose	lines of hose
60	last line	results	result

CONTENTS

	PAGE
Historical	1
Black Rot	4
Leaf Disease	6
Die Back and other Leaf and Shoot diseases... ...	11
Indirect effect of spraying	13
Bordeaux mixture	16
Adhesives and spreaders	22
Effect on leaf retention	27
Burgundy and other copper containing mixtures ...	30
Fungicidal dusts	33
Strength of mixture	34
Time of spraying	37
The results of spraying	47
Spraying machinery	51
Progress of spraying in Mysore	66
Summary	66



Digitized by the Internet Archive
in 2025

https://archive.org/details/mysore-coffee-experiment-station-bulletin_1933_9

SPRAYING OF COFFEE.

HISTORICAL.

Probably, the first mention of spraying against fungus disease in tropical countries was made in Ceylon and Java in connection with the serious ravages of Leaf Disease, *Hemileia vastatrix*. In Ceylon, Bordeaux mixture does not appear to have been tried though various other mixtures including lime-sulphur were suggested but none gave sufficiently favourable results to lead to any extended use.

In Java, where investigations were carried on after the appearance of Millardet's work in Europe, Bordeaux mixture was tried and was found effective in checking the disease to some extent. The opinion of the investigators was unanimous, however, in regarding spraying as impracticable under estate conditions and the transference of attention to resistant varieties and species of coffee did not encourage further investigation.

It is thus clear that the ability of Bordeaux mixture to mitigate Leaf Disease in coffee was recognised as long ago as 1886, when Burck (5) first investigated the disease in Java. The general opinion of its impracticability on a large scale prevented its becoming an estate method of control.

The enormous reduction of coffee producing areas in Ceylon and South India, and the replacement of Arabica coffee by various resistant coffee types in Java during the 25 years following Burck's work did not tend to encourage further investigation on the use of fungicides against Leaf Disease. Writers, such as, Delacroix (11) describing tropical plant diseases certainly wrote of Bordeaux mixture as a means of controlling coffee Leaf Disease, but there is little evidence that such recommendations were ever translated into estate practice. The difficulties of water supply, spraying machinery and application seemed in those days insurmountable. It is doubtful whether those who recommended the use of Bordeaux envisaged more than the spraying of a few acres where the disease happened to occur with a special virulence.

As far as South India is concerned, interest in spraying plantation crops was rearoused by the results obtained by Coleman (7) against the Phytophthora disease of areca. His experiments were started in 1908 and demonstrated that Bordeaux mixture was an effective means of control, and, what is of greater importance, that spraying areca palms was practicable in gardens of normal size in Mysore. This must be regarded as the first application of Bordeaux spraying to South Indian crops.

The study of the effect of spraying against coffee Black Rot was taken up shortly afterwards and the first experiments were started in Koppa in 1911 by the Mysore Department of Agriculture. The work was continued in the following years by the Department and the value of spraying against the disease was also studied by *Frattini* (12) from 1914 to 1917. They showed that Bordeaux spraying was very effective in the control of Black Rot. Definite recommendations were made by Coleman, Venkata Rao and Narasimhan (9) in their bulletin on Black Rot published in 1923. In this connection mention must be made of the work of Mr. T. Narasinga Rao (29) of Chikmagalur in testing out spraying against Black Rot under the auspices of the Mysore Agricultural and Experimental Union.

Turning to Leaf Disease, the earliest records of the application of Bordeaux spraying to the control of this disease is contained in an article in the Journal of the "Mysore Agricultural and Experimental Union" in 1920 where Dr. Coleman (8) communicated a letter from Mr. H. Kerr of Kothencool Estate in the Bababudans detailing his experiments. Mr. Kerr first started spraying against Leaf Disease in 1917 and the results were so successful that over 75 per cent of the estate (95 acres) was sprayed in 1918 and over 60 per cent in 1919 and 1920. Sometime shortly afterwards, the estate was sold and no further reports are available. In the Bababudans, the interest in spraying against Leaf Disease was maintained by Messrs. Denne and Oliver who started spraying at about this time.

Spraying against Leaf Disease was carried on to some extent in the Bababudans during the next 6 or 7 years, after which it became more general. Mr. Kerr's spraying must be regarded as the first on an estate scale carried on systematically over several years. It is interesting to note that his costs, at Rs. 19 per acre, differ but

slightly from present day costs for a full strength mixture (5-5-50).

In the years following 1920, a considerable amount of work was done on spraying against Black Rot and Leaf Disease in Coorg and Mysore. For a number of years, however, it did not get beyond the experimental stages, largely on account of the practical difficulties.

A spraying experiment was included in the activities of the Sidapur Experiment Station from 1920 and continued until the work was closed in 1926. Munro (24) reporting on the experiments in 1926 stated " Spraying is the most useful method of increasing crop in old coffee."

Experiments on a somewhat larger scale were started at Purchikadu Estate in Coorg at the suggestion of Anstead (1) in 1922 and a report presented in 1923 by Munro (22). From this experiment, it was concluded that spraying led to a marked improvement in yield and in appearance of the coffee and that a mixture of 5 lbs. copper sulphate and 5 lbs. of lime in 50 gallons of water was sufficiently strong. A still weaker strength appeared fairly satisfactory but was not recommended as the trials had been in progress for too short a time. Apart from a reference by the Madras Government Mycologist (35), some months later in 1923, the only further report on the experiments appeared in the Sidapur Station Report for 1923-24.

In Mysore, the Report of the Agricultural Department for 1924-25 stated that demonstrations were carried out in Koppa, Mudgere, Chikmagalur and Saklespur Taluks on a total of about seven acres, and that materials were sold to four planters sufficient for spraying 30 acres. This spraying was undertaken primarily as a means of Black Rot control.

The first revival of interest in spraying against Leaf Disease following the experiments of Munro seems to have occurred in the Shevaroy District in 1925, when 14 acres were sprayed in July of that year with 2 gallon Holder sprayers. In the following year, two estates attempted to spray their whole acreage. This attempt raised the problem of the most suitable type of sprayer, as for large areas the 2 gallon pressure sprayer did not prove itself entirely satisfactory.

The work in the Shevaroys aroused considerable interest and in response to requests, Mr. E. H. A. Travers-Drapes summarized his experiences in the Planters' Chronicle (37).

Spraying, as a result of the work of the Mysore Department of Agriculture with respect principally to

Black Rot, and of Munro, and planters in the Shevaroys with respect to Leaf Disease showed a steady increase in popularity from that time but the acreages done annually remained small. The problem was almost entirely one of suitable machinery as the Holder 2 gallon Knapsack sprayer did not give a very even spray and involved considerable waste of time in filling and pumping with a consequent increase in labour requirements.

The solution of this problem was provided by the experience of rubber planters who had adopted spraying against secondary Leaf Fall on the advice of Ashplant (2) in 1924. They had used Drake and Fletcher's double suction pumps with lengths of hose and spray rods and found them highly satisfactory. It was realised about 1927 that this type of sprayer could be used with advantage on coffee, if the long spray rod was replaced by a shorter one and experiments were carried out successfully with this sprayer by Munro in 1927 (25). This type of sprayer came into use in Mysore, as a result of its introduction by Mr. Walmsley in 1927 and its advent was quickly followed by a very rapid extension of spraying both in Mysore and in other districts including those where but little spraying had previously been attempted. With regard to Mysore, the rate of spread can be realised from Dr. Coleman's (10) remarks in the first bulletin of the Mysore Coffee Experiment Station. He wrote (1930) "Three years ago, there could not have been more than 500 acres of coffee sprayed in the State. During the present year, the area has risen to more than 5,000 acres which must have led to an increase in the value of the crop by at least Rs. 4 lakhs."

Further developments in the improvement of methods, materials and machinery, in more accurate timing of spraying, and observations on other diseases in connection with which spraying has been found advantageous, form the subject matter of the present bulletin.

Black Rot.

[*Corticium Koleroga (Cooke) Von Hohn.*]

The outbreak of this disease occurs in areas where the rain fall is heavy, approximating to a total of 80 to 100 inches. In estates with a rainfall of 60 inches, the attack is not serious. More than a high precipitation, a

heavily moisture laden atmosphere with no dry spells, is conducive to the spread of the disease. The disease breaks out in its worst form, in portions of an estate, sheltered from the wind where the mist hangs heavily.

The chief symptom of the disease is the blackening of the affected leaves, which hang suspended by fungus strands. The presence of a fungus web, which grows over the lower surface of the leaves and over the berries, and which consists of a mass of closely woven mycelium, is easily seen when the leaves are fairly dry. On the petioles and small branches, the film constricts itself into a compact ribbon of parallel hyphæ.

The course of the disease may be divided into two definite stages, the early spore stage and the late sclerotial stage. Early during the outbreak of the disease, the fungus gives rise to innumerable round or oval structures each of which produces four elongated, club-shaped, minute spores borne on the tips of slender threads. These spores are not easily made out owing to the fact that they get readily detached and washed off by the rain. The rapid spread of the disease during monsoon weather is mainly by means of these spores. At this stage, the fungus develops on the leaf as a surface film, which can be easily peeled off when wet. Later, in the course of development, the lower surface of the affected leaf appears to be studded with a large number of clumps made up of closely compacted fungus threads (microsclerotia). It is only at this stage that the fungus enters into the leaf tissues and causes the characteristic blackening. The cause of blackening of the leaf has not been clearly understood hitherto, as the fungus has been believed to have only surface growth. As observed by one of us, the penetration of the tissues by the fungus takes place at the time of the formation of the fungus clumps, and the blackening is probably caused by the secretion of toxic substances by the fungus at this time. The fungal clumps enable the fungus to tide over the hot weather, and form the chief source of infection during the following monsoon as they send out a fresh growth as soon as favourable conditions of moisture return.

As during the early stages of growth this fungus lives on the surface of leaves, twigs and berries, it can be controlled by spraying with remarkable ease. As Black Rot is a disease practically confined to that season of the year covered by the South-west monsoon, one efficient and

thorough spray applied immediately before the beginning of that monsoon is sufficient to ensure almost absolute protection from this disease.

Leaf Disease.

Coffee Leaf Disease (Hemileia vastatrix) presents an entirely different problem from Black Rot. It differs in its relation to the leaf it infects and in its relation to the climatic conditions which determine the rise and fall of both diseases. It is in a sense almost accidental that both diseases are controllable, at least, in a part by one of the two usual spray applications.

In order to understand the problem of control presented by Leaf Disease, some preliminary account of the disease itself is necessary. The ordinary appearance of a diseased leaf in the field is familiar to all coffee planters but the history of the origin and development of the disease spots is less well known and it is on a knowledge of this that successful control measures must be based.

The Leaf Disease pustules found as orange yellow spots on the lower side of a coffee leaf represent the reproductive stage of the fungus, the orange yellow dust powder which covers these spots being the reproductive bodies or spores. From an individual spore, we may trace the history of a diseased spot. The spores consist of minute kidney-shaped bodies provided with a stout wall ornamented with spinelike projections on the convex surface. They become detached when they are ripe and can be transported by wind, animals or insects or washed down by rain from one place to another. Naturally, the wastage of these spores is colossal, as only those which happen to find a resting place on the under side of a coffee leaf are able to produce a fresh disease spot. Those which fail to reach such a situation have no further importance as far as the disease is concerned.

The spores which reach the under surface of the coffee leaf under certain conditions of light and moisture, proceed to germinate by pushing out a narrow tube which grows until it reaches one of the stomata or pores which are present all over the lower surface of the leaf. Having reached the stoma, the end of the germ tube swells up and then sends a fine infection hypha down into the air spaces in the interior of the leaf. The protoplasm filling the germ tube soon flows into the infection hypha and

from it into the branches formed inside the leaf. This leaves nothing but the empty spore and germ tube wall on the exterior surface of the leaf.

Spore germination studies and studies of the preliminary stages of infection have shown that for spore germination, the presence of water droplets on the leaf surface is necessary and at least during the first stages of germination, the presence of bright light prevents development. This is clearly shown by some spore germination experiments carried out in 1931 which were reported in the Annual Report of the Coffee Scientific Officer, 1931-32 (20). The results of a typical experiment are shown in Table 1.

TABLE 1.—*Showing the Effect of Light and Darkness on Spore Germination.*

	Per cent germination	*No. of tests*
1. Light (north window)	... 2·0	3
	1·2	3
2. Darkness (closed cupboard)	... 49·2	3
	38·1	3

The experiments were carried out by dusting spores of the fungus on drops of water on glass slides enclosed in moist chambers. Half of the moist chambers were placed in a dark cupboard and the other half kept on a bench in the light from a north window. The percentage germination was determined by counting the germinated spores after 24 hours. Other experiments suggested that this almost total inhibition of germination occurred only with bright light. Dull light, such as, occurred on a shelf away from the window did not have such a strong effect. The work was somewhat handicapped by technical difficulties so that there is yet no evidence as to the limits of light intensity within which no depression of amount of germination takes place. The commencement of germ tube formation occurs three or four hours after the spore has come in contact with the water drop, though the actual time will vary with the condition of temperature. The whole process of penetration of the leaf is completed in about 24 hours.

The fungus continues its growth in the air spaces of the leaf and proceeds to put out short branches which penetrate into the leaf cells and extract nourishment for the further development of the fungus. This growth and

development goes on for about ten days, when a visible indication of the fungus in the leaf appears in the shape of a minute yellow spot on the lower leaf surface. This yellow spot increases in size and visibility and about the sixteenth day the first signs of the production of the spores can be seen on it. During this period, the fungus in the interior has been massing hyphæ under the stomata in the centre of the yellow spot and from these masses, branches are put through the stomata and spores formed on them. The life cycle is completed and fresh spores are available for the further spread of the disease.

Like all plant diseases caused by fungi, Leaf Disease is influenced in various ways by climatic conditions and the influence of these conditions determines the severity of the attack. The situation is complicated, however, by the fact that the same climatic conditions may affect different stages in the life cycle in different ways. A considerable mass of data both from field and laboratory work has been accumulated during the last two years on the question of the effects of climatic conditions of Leaf Disease. While a good deal yet remains to be learnt, certain general conclusions have been reached which have a direct bearing on the problem of control by spraying and these will be summarised here.

The main climatic factors may be considered as rainfall, humidity, wind, light and temperature, and some or all of these may affect spore distribution, spore germination, leaf infection, vegetative development within the leaf and spore production.

It has been said above that spore germination requires the presence of liquid water on the under surface of the leaf and the absence of light. The requisite water may be provided by rain or even more efficiently by mist and dew, while the necessary conditions of darkness are provided during the night. It is at once clear that Leaf Disease can be active whenever there is rain or heavy mists or dew. The actual duration of such periods in the year will vary widely in different districts but it is obvious that the periods will be sensibly longer than those which are suitable for the development of Black Rot. At the Coffee Experimental Station, Balehonnur, favourable conditions for Leaf Disease may be considered to extend in greater or less degree from April until December.

Spore distribution is affected by wind and rain. Strong wind causes a wide dissemination of spores which

means a wide distribution of the disease if conditions are favourable for spore germination, but at the same time it hinders the development of severe localized attacks of the disease. Rain affects distribution in that if it is heavy and continuous, large numbers of spores are washed off the pustules and are lost in the soil, or spores are water-logged and soaked so that their power of germination is greatly reduced.

The effect of climatic conditions on the growth and development of the disease within the leaf is less easy to study and has so far received less attention as the problem is greatly complicated by the simultaneous effect of the climatic conditions on the normal functions of the leaf and their interaction on the development of the fungus. There is however, a little evidence to suggest that spore development is hindered by low light intensity and also perhaps by low temperatures. Humidity also probably plays a part in determining the rate of spore production but this question has received no attention as yet.

These conclusions, coupled with detailed observations extending over two years enable the following summary to be made with regard to the influence of climatic conditions on the progress of Leaf Disease attacks in north Mysore. Leaf Disease activity starts with the first rains in April and continues up to the monsoon with greater or less intensity depending largely on the number of rainy days. Development continues through the south-west monsoon relatively slowly, being checked by periods of continuous heavy rain. Following the south-west monsoon, development becomes very rapid with the advent of the showery-sunny weather of the north-east monsoon and continues with the help of mists and dew through December as long as there is available leaf for infection. Through the dry months, the disease is in abeyance and as infected leaves drop the trees enter the hot weather with only a few disease spots still alive on the leaves. Of course more diseased leaves may hang about on the trees growing in damp ravines or near streams and these must be regarded as important sources of new attacks.

So far no other host of the disease has been identified with certainty, as those strains or species of Hemileia found on Gardenia gummifera and Vangueria do not appear to infect coffee. Experiments with the Hemileia on the latter plant failed to give infection on coffee. It

seems therefore, that the preservation of the disease over the unfavourable season depends on the diseased spots developed on leaves in the previous season.

To make the conclusion more general the following tabular comparison is given:—

(*a*) Conditions favourable to the rapid development of severe attacks:

Shelter from wind.
Intermittent rain, dew or mist.
Ample sunshine. Very light overhead shade.
Moderately high temperature.

(*b*) Conditions unfavourable to the rapid development of severe attacks:

Exposure to wind.
Absence of rain, dew or mist.
Heavy and continuous rain.
Low light intensity. Heavy overhead shade.
Low temperature.

(*c*) Conditions favourable to chronic Leaf Disease attacks:

Short dry weather.
Much mist and dew in the dry months.
Much coffee growing in damp ravines or near streams, etc.

The actual position with respect to the disease at any particular time will depend on the balance of favourable conditions for the disease during the preceding period.

The effects of the disease in reducing the area of healthy leaf, in causing leaf fall, and in predisposing shoots to Die Back with its consequent loss of partially developed crop are well-known. At the same time the loss of crop caused by the disease is by no means limited to the obvious fall of half formed cherry. The reduction in functional leaf area prevents the accumulation of sugars and starches, the formation of which depends on healthy leaf areas, and it is on these that fruit production depends to a high degree. Thus a heavy attack of Leaf Disease means that there is little reserve of starch and sugar for the formation of flower bud for the coming season, and a large part of what reserve there is, is utilised in producing fresh leaves to replace those lost through disease. These leaves are rarely able to accumulate sufficient reserves to provide a big crop though the tree may look healthy and leafy at blossom time. The loss of leaf in the latter half of the

year is at present unavoidable in districts where Leaf Disease is an annual recurrence except through spraying and in such areas it must be regarded as an agricultural operation of primary importance.

With respect to spraying, there are two features of the disease which require special emphasis as it is on a due recognition of these, that the value and limitations of spraying must be based. In the first place the life cycle of Leaf Disease is passed almost wholly in the interior of the leaf and with the exception of a period of about 24 hours between the germination of the spore and the completion of penetration, it is out of the reach of fungicides. Hence all spraying operations are designed to provide a fungicide on the leaf which can come into action during this short period. Secondly, penetration of the leaf occurs only through the stomata so that any spore reaching the under surface of a leaf has to grow a certain distance on the leaf surface before it can penetrate. Some measurements made by one of us show that stomata occur at the rate of 100—120 per square millimetre or 62,500—75,000 to the square inch. It thus appears that the distance that the germ tube has to grow is not very great, and for complete protection, Bordeaux particles must occur so frequently that a germ tube cannot fail to encounter a copper containing particle of spray before it reaches a stoma. Herein lies the great importance of an even spray coating over the leaves.

Die Back and other Leaf and Shoot Diseases.

While spraying was previously taken up in connection with Leaf Disease and Black Rot, it soon became clear that it also provided an excellent control of Die Back. The favourable effect became clear when investigations by one of us showed that in general Die Back was a debility disease brought about by the loss of leaf following severe attacks of Leaf Disease. While a fungus *Colletotrichum coffeanum* (Glomerella sp.) was regularly isolated from Die Back attacked shoots, little success attended inoculation experiments, even after attempts at exhausting experimental plants. Further, Die Back was never found to attack shoots with several pairs of leaves, though a shoot tip which was defoliated might die back to an older pair of leaves. Observation showed that while defoliation was not necessarily followed by Die Back, Die Back never occurred without defoliation. Prevention of defoliation by

Leaf Disease resulted in the reduction of Die Back to negligible proportions. This is shown by the following figures of percentage on cropping shoots, showing Die Back in counts on 60 branch systems in sprayed and unsprayed plots (See Table 2). It must be mentioned that an attempt has been made to obtain evidence of the efficiency of the spray by the following technique of sampling, which has been adopted throughout the course of these experiments.

The method consists of taking 60 typical branch systems, defined by the number of joints or nodes, for each treatment, counting the number of leaves and the number of growing points and calculating a figure for the number of leaves per growing point for each branch system. From the total of 60 branch systems a mean and its standard error are calculated. The observations have been made each year for the last three years at the end of September, just before the disease reaches its maximum and before the amount of crop being carried has exerted a noticeable influence on leaf fall.

TABLE 2.—*Percentage of Die Back on Sprayed and Unsprayed Branch Systems.*

	Sept. per cent	*Feby.* per cent
0·5 per cent May and September spray ...	3·1	3·8
Control. Not sprayed ...	8·8	23·5
0·5 per cent May spray. ...	2·1	8·5
Control. Not sprayed. ...	4·9	17·0
0·5 per cent September spray ...	9·6	17·7
Control. Not sprayed ...	11·1	16·2

While there are no other serious leaf and shoot diseases, the occasional severe attacks of Brown Eye Spot (Cercospora coffeicola) in nurseries can be prevented by spraying nursery plants. The cost of this is trifling and it contributes to a considerable degree towards providing healthy vigorous young seedlings.

Pink Disease (Corticium salmonicolor), while rarely obvious enough to warrant special measures may be checked by spraying. As its climatic preferences strongly resemble those of Black Rot, it is prevented from wide-spread development by measures against this disease.

Indirect effect of Spraying.

In addition to the direct effect of Bordeaux spraying in controlling the major leaf and shoot diseases of coffee there are certain indirect effects which deserve consideration as they are of some considerable importance.

The principal of these effects relates to two insect pests, borer *(Xylotrechus quadripes)* and scale insects (principally *Coccus viridis*). The former of these, the white borer, is by far the most formidable insect pest of coffee in Southern India and so far has proved itself almost impossible to control effectively. It has however, long been known that heavy overhead shade was unfavourable to the egg laying habits of the female, and in the badly infested districts, this fact has been made use of. Definite evidence to support this view was obtained by the late Dr. Kunhikannan (15) in breeding experiments. Beetles were enclosed in cylinders on stems, one set under a dark cloth, another under white cloth to simulate conditions of shade and of light obtaining in an estate. While 120 eggs were found to be laid in the latter case, no oviposition was noticed in the shaded cylinder. Such heavy shade as is requisite to keep down borer within manageable limits has its re-action in the reduction of cropping capabilities. This reduction has had to be accepted, however, in order to preserve the trees from total loss.

During the last two years, in a series of spraying experiments at the Experimental Station, Balehonnur, involving a large number of sprayed strips of coffee interspersed with unsprayed strips, it has been found that the borer removals in the unsprayed strips were about five times as great as in the sprayed strips, indicating that spraying was exerting a markedly favourable influence on the reduction of borer.

TABLE 3.—*Showing Borer Removals in Sprayed and Unsprayed Plots.*

	Experimental Station, Balehonnur.		
	1931–32 per cent	1932–33 per cent	Mean per cent
Bordeaux sprayed plots ...	3	1·4	2·2
Burgundy sprayed plots ...	4·9	2·3	3·6
Control, unsprayed plots ...	10	14·5	12·3

The reason is not far to seek. It has been established that the main egg laying season of the borer occurs in October which coincides with the periods in which Leaf Disease attacks are often at their maximum. Leaf Counts, to be considered in detail below, showed that, at the end of September, sprayed plots carried about twice as much leaf as unsprayed plots. This enormous difference in amount of leaf means an equally enormous difference in the shading effects of the crown of the bushes on the main stem. Thus the stems of the sprayed coffee during the flight period of the borer are under a shade approximately twice as heavy as those of similar unsprayed coffee.

The influence of this leaf cover is certainly exaggerated in the experiments in that no doubt there has been a concentration of the borer beetles in the unsprayed plots which would not otherwise occur. However, it affords strong indication that Bordeaux spraying, by its effect on the amount of leaf, does exert a marked influence in reducing borer. This has been borne out by estate experience. That the incidence of borer attack is diminished to a considerable extent by spraying, is borne out by the following figures kindly supplied by Mr. E. H. Young of Ossoor Estate, Hassan District, Mysore.

TABLE 4.—*Showing Borer Removals on Ossoor Estate prior to and after Spraying.*

Total No. of trees removed during four years (1925–1928) prior to spraying	...	1,07,223
Total No. of trees removed during four years (1929–1932) after spraying	...	36,620

The spraying work was started during 1928, and has since been regularly carried on.

The problem of the indirect effect of spraying on scale insects is much more obscure, but frequent reports have been received that Bordeaux or Burgundy spraying has resulted in a considerable increase in scale insect attack. The matter has not been thoroughly investigated as yet, though there is an apriori probability that spraying may lead to an increase in the bugs as a consequence of the destruction of the entomogenous fungi, *Empusa lecanii* and *Cephalosporium lecanii* which help to keep them in check. An enquiry carried out in 1932 by Capt. Windle and reported in his recent book " Modern Coffee Planting "

suggests that the increase in scale due to spraying has been over estimated, and that where comparisons were possible, the severity of bug attacks was as high in unsprayed coffee as in sprayed. He concluded that the numerous reports in 1932 of severe bug attack on sprayed coffee were attributable to extremely favourable climatic condition during that year, and that severe attacks were equally prevalent on unsprayed coffee. Recent observations on thoroughly sprayed plots on the Coffee Experimental Station have showed the presence of the white fungus (*Cephalosporium lecanii*) on green bug attacking coffee.

It is obvious that any fungus present on bugs at the time of spraying with Bordeaux is liable to destruction and also that bugs covered by a film of Bordeaux particles will be protected against infection. The effect of the first of these points on the future of the fungus depends very largely on the number of other hosts of the bugs in the neighbourhood and the status of the bug and its parasitic fungi on these hosts. If other hosts with bug parasitized by the fungi are available, the check due to spraying the coffee should only be temporary as new bug developing on the coffee will be free from a coating of spray and open to infection by fungus spores derived from other bug colonies on other hosts.

In the absence of other bug hosts, it might be advisable to keep some bug-infested coffee plants on which the fungi were present unsprayed as a reservoir of spores which might later have an opportunity of attacking fresh bugs on the sprayed trees.

These remarks must be considered as purely of a tentative nature in the absence, at present, of any thorough investigation of the biological relations between the fungus and the bug. It is hoped to commence a study of this subject in the near future, with special reference to the effect of spraying on the activities of the parasitic fungi.

To a large extent this problem will be solved, if a spray mixture can be used, which will have the properties of both a fungicide and an insecticide. Such combination sprays have been successfully applied for the simultaneous control of apple scab (Venturia inequalis) and codling moth in America. Investigations are in progress to find out how green bug on coffee can be controlled by the addition of an insecticide to Bordeaux mixture.

The two latter tests are the more satisfactory and it is desirable that one or the other should be employed as a control of the mixing process.

Method of mixing.— Bordeaux mixture is not a definite chemical compound but a mixture in various proportions of a number of basic sulphates of copper with or without an excess of lime. The physical properties of the mixture depend to a great degree on which of these basic sulphates predominate and this, in turn, depends to a high degree on the method employed in mixing the two ingredients. With an ordinary chemical action, such as, say the precipitation of silver chloride by adding a solution of common salt to a solution of silver nitrate (Lunar Caustic), it does not matter which solution is poured into the other, nor what the concentration of the reacting solutions is within wide limits, but the case of mixing Bordeaux is in no way comparable with this simple chemical reaction.

Methods of mixing may be divided under three main heads:—

1. The pouring of milk of lime into copper sulphate solution.
2. The pouring of copper sulphate solution into milk of lime.
3. The pouring of the two simultaneously into a third vessel

Though the ultimate products of the reaction are identical in the above cases (see Martin (17) p. 78), the physical properties of the precipitate are influenced by the method of mixing. The ideal spray is one in which the precipitate is composed of finely divided particles held in suspension in the mixture, the rate of settling being slow. It has been found that a mixture is obtained by the second method of preparation, which settles much more slowly than that obtained by the first method. The third method, namely, pouring the two solutions together, does not seem to have any special merits. The disadvantage of this method is that the two solutions can with difficulty be poured in simultaneously and that usually after all the copper sulphate solution has been poured in, the heavier particles of lime at the bottom of the container, are poured in, belatedly after the main reaction has taken place. An additional disadvantage is the increased requirement of containers.

In estate practice, the preparation of the mixture is somewhat troublesome owing to the question of containers. To obviate this difficulty at least to some extent, a stock solution of copper sulphate is used at the rate of 1 lb. per

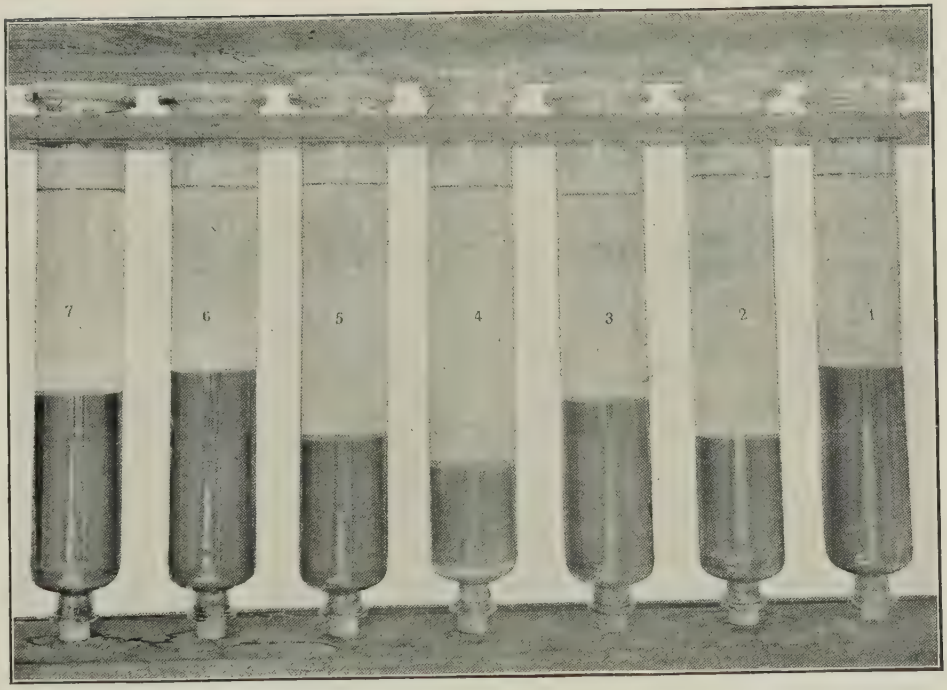


FIG. 1.

Showing difference in rate of settling of Bordeaux mixture, prepared in different ways and kept in cylinders. Photo taken 6 hours after preparation. For details of preparation see Text p. 19.

gallon, which will keep indefinitely. The following different methods of preparations of the mixture were tried to study the rate of settling of the precipitate:—

1. Concentrated copper sulphate solution added to dilute milk of lime.
2. Concentrated milk of lime added to dilute copper sulphate solution.
3. Dilute copper sulphate solution added to concentrated milk of lime.
4. Dilute milk of lime added to concentrated copper sulphate solution.
5. Dilute milk of lime added to dilute copper sulphate solution.
6. Dilute copper sulphate solution added to dilute milk of lime.
7. Dilute copper sulphate solution and dilute milk of lime poured together.

The mixtures were placed in glass cylinders and their rate of settling studied.

Figure 1 shows the variation in the rate of settling of the various mixtures. It will be seen that the mixtures in cylinders 1, 3 and 6 prepared by pouring copper sulphate solution into milk of lime have settled more slowly than those in cylinders 2, 4 and 5 prepared by pouring milk of lime into copper sulphate solution. A comparison of the mixtures, in cylinders 1 and 3 is interesting. According to 0. Butler (6), the best result is obtained by adding weak copper sulphate solution to strong milk of lime. Pickering (32), however, found that the most suitable mixture is obtained when concentrated copper sulphate solution is added to the dilute milk of lime. The results obtained by us confirm Pickering's findings.

If concentrated stock solutions, without dilution are mixed, the settling is very rapid.

The preparation of the mixture is influenced by other factors, such as, the rate at which one solution is poured into the other, and the temperature of the two solutions. It was found by Newton, Johnston and Yarwood (31) in Canada, that mixtures prepared by pouring rapidly one solution into the other settle much sooner than those where the pouring was done slowly. They also found that adding one of the solutions hot to the other cold, led to an inferior product from a physical standpoint.

Physical Properties.—Fresh Bordeaux mixture properly prepared is gelatinous in appearance and light blue in colour, and settles slowly on standing. The character of the precipitate determines the adhesion of the spray. The precipitate is believed to be composed of colloidal

is above normal. It was found by Kelhofer (13) that the fresh condition of the mixture could be conserved by the addition of sugar. He added about 4 lbs. of sugar to 50 gallons of mixture. He found that even traces of saccharose (0·005 per cent) added to Bordeaux mixture retarded the crystallisation of the precipitate.

Experiments to test the effect of the addition of jaggery to Bordeaux mixture in relation to settling and adhesion were carried out by Ashplant, (2) using 3 lbs. of jaggery to 50 gallons, with the result that jaggery Bordeaux was found to settle more slowly than plain Bordeaux. Experiments carried out by us indicate that the addition of $\frac{1}{4}$ lb. jaggery to 50 gallons of mixture considerably influences the nature of settling and the colour of the precipitate on standing. Figure 4 shows the effect of addition of jaggery to plain Bordeaux and Casein Bordeaux. In both the cases the settling is slower when jaggery is added than without it. In addition it was noted that the supernatant liquid in Casein jaggery Bordeaux, was lighter in colour, than in Casein Bordeaux, where on account of the separation of free copper, the liquid is tinged violet. While the precipitates of mixtures without jaggery ultimately change to a bluish violet colour, those with the addition of jaggery have retained their original fresh colour after three months. Kulisch (14) also found that sugar Bordeaux could be kept in a fresh condition all through the summer and used successfully in preventing grape Mildew. Lutman (16) obtained similar good results by the use of 200 grs. of sugar to 50 gallons of mixture. The presence of sugar retarded the crystallisation of the Bordeaux precipitate.

This method of Bordeaux preservation has an important bearing on the problem of spraying during the rainy season. Owing to uncertain weather in coffee and areca estates, it often happens that heavy rains interfere with spraying and consequently the mixture has to be stored till the rain stops. It is the practice in some areas to throw away the mixture if it is two days' old, leading to unnecessary waste. If jaggery is added to the mixture, the physical condition of the mixture can be preserved.

Adhesives and Spreaders.

The importance of adding a spreader to Bordeaux mixture has not generally received the consideration it

deserves, but in South India and especially in Mysore, its use had been advocated nearly twenty-five years ago. Owing to the heavy rainfall in areas where spraying against the Koleroga (Phytophthora arecae) of arecanut has been carried on, the addition of an adhesive to Bordeaux mixture has been considered necessary for protection against rain. An adhesive made up by boiling 2 lbs. of resin and ½ lb. of soda ash, and added to 25 gallons of Bordeaux mixture has been found to be quite effective in spraying against areca Koleroga. Further extensive trials with other adhesives have since been made with the results that lime caseinate and linseed oil have been found to be effective.

In order to test the relative value of various adhesives, and their influence on the nature of Bordeaux mixture, a series of experiments were taken up. At the outset, trials were made, with various adhesives, such as, resin soda, lime caseinate, linseed oil, tannin, mucilage from prickly pear and mucilage from "*Honne*" (Pterocarpus Marsupium) but it was soon found desirable to restrict attention to the first three which were found to be more promising than the others. The object of the experiments was to note the effect of adding the adhesives on the settling qualities of the Bordeaux mixture and on the actual retention of the copper precipitate. The following paragraph gives the methods of preparation of these three adhesives :—

1. Resin soda is prepared by boiling 2 lbs. of resin, ½ lb. of soda ash in one gallon of water (7).

2. Lime caseinate is prepared as follows :—½ lb. of fine ground casein is soaked in ½ gallon water, and to this is added a lime suspension made up of ½ lb. lime in ½ gallon water. The whole is mixed well for 10 minutes (26).

3. The addition of linseed oil is calculated on the basis of the amount of solids contained in the mixture. It is added at the rate of one fluid ounce of oil to 1 lb. of solid in the mixture (28). Thus for 5 : 5 : 50 Bordeaux mixture 10 fluid ounces of linseed oil are added. The whole is then thoroughly stirred to lead to an emulsification of the oil. In these preliminary experiments the resin soda and lime caseinate adhesives were added at the rate of one gallon of adhesive to 24 gallons of mixture.

To study the settling quality, the mixtures were placed in uniform glass cylinders as follows:—

1. Concentrated milk of lime into dilute copper sulphate solution.
2. Concentrated milk of lime into dilute copper sulphate solution with lime caseinate.
3. Concentrated milk of lime into dilute copper sulphate solution with resin soda.
4. Concentrated milk of lime into dilute copper sulphate solution with linseed oil.
5. Concentrated copper sulphate solution into dilute milk of lime.
6. Concentrated copper sulphate solution into dilute milk of lime with lime caseinate.
7. Concentrated copper sulphate solution into dilute milk of lime with resin soda.
8. Concentrated copper sulphate solution into dilute milk of lime with linseed oil.

At the outset it was noticed that the addition of adhesives does not affect the superiority of the mixture prepared by pouring concentrated copper sulphate solution into dilute milk of lime. If we consider the effect of spreader on the flocculence of the precipitate we find that the addition of resin soda leads to the highest degree of flocculence followed in order by casein and linseed oil. This leads to a marked difference in the rate of settling. Thus resin soda Bordeaux settles most slowly followed in order by casein Bordeaux and linseed oil Bordeaux. Figure 2 shows these differences clearly. After the precipitate has settled to some extent, marked variations are to be seen in the colour of both the precipitate and the supernatant liquid.

TABLE 5.—*Showing Colour Standard (Ridgeway) of Precipitate and Supernatant Liquid in Different Mixtures*:—

	Precipitate	*Supernatant liquid*
1. Plain Bordeaux ...	Methyl Blue ...	Clear.
2. Casein Bordeaux ...	Leitch's Blue ...	Light Lavender Violet.
3. Resin Soda Bordeaux.	Light Methyl Blue.	Pale chalcedony yellow.
4. Linseed Oil Bordeaux.	Light Cerulean Blue.	Lighter yellow than in No. 3.

In casein Bordeaux there is a separation to some extent of free copper as indicated by the violet tinge of the supernatant liquid. A similar phenomenon has been observed by Newton, Johnston and Yarwood (31) in their

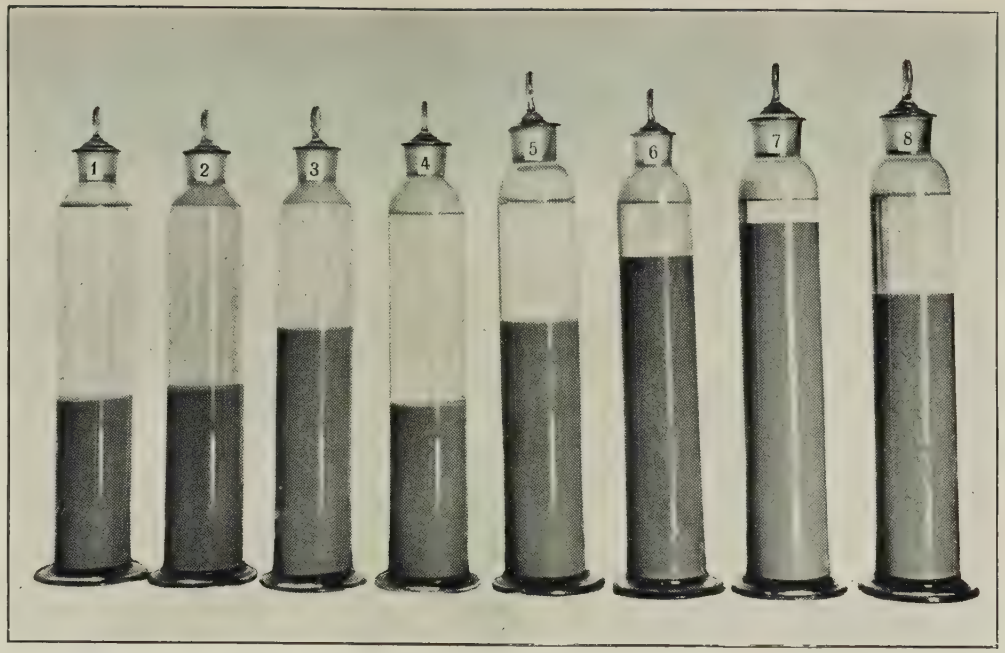


FIG. 2.

Bordeaux mixture in cylinders to show the effect of addition of adhesives on the rate of settling. Cylinders 1-4 with Bordeaux mixture prepared by adding concentrated milk of lime to dilute copper sulphate solution. Cylinders 5-8 with the mixture prepared by adding concentrated copper sulphate solution into dilute milk of lime. 1 and 5 Plain Bordeaux. 2 and 6 Casein Bordeaux. 3 and 7 Resinsoda Bordeaux. 4 and 8 Linseed oil Bordeaux. Photo taken 4 hours after preparation.

during the pre-monsoon season. With this end in view, the following technique was adopted:—

The collections were made by selecting pairs of adult leaves in early June, marking the pairs with labels and removing one member of each pair. The pairs were selected as far as possible from similar positions on the tree such that they were neither liable to heavy spray deposits (*e.g.*, from branches low on the tree or projecting from the "head") nor likely to have been missed by the spray. The collected leaves were made up into batches of ten, the origin of each leaf being recorded by noting the row and plant number and its position on the tree. Ten sets of ten leaves were sent in from each plant so that there were thirty from each treatment. In September, the remaining member of each pair was collected and the leaves made up into sets of ten corresponding to the sets made up in June. The percentage recovery was between 80 and 90 per cent. For missing leaves were substituted suitable leaves from a neighbouring position on the tree. Definite leaf areas were cut out by means of a template and the copper content analysed. The first set of leaves collected during early June served as an approximate indication for evaluating the percentage copper retained after the rains in the second set. The following table gives the result of analysis of the copper still retained on the leaves after the monsoon:—

TABLE 6.—*Showing Percentage of Copper Retained on Coffee Leaves sprayed with Different Mixtures.*

Plain Bordeaux	...	...	42·5 ±1·7 per cent
Linseed Oil Bordeaux	...	...	47·01±2·6 „
Resin Soda Bordeaux	...	...	41·57±2·06 „
Casein Bordeaux	...	...	55·01±3·1 „

It will appear from the above table that the amount of copper retained in the casein Bordeaux series is significantly higher than that in either of the other series. The results in the case of the other two spreaders do not indicate a retention of copper significantly greater than that in the case of plain Bordeaux. Similar data have been obtained by Schaffnit (34) for casein Bordeaux, who found that the amount of copper retained was approximately double that obtained for plain Bordeaux. Newton, Johnston and Yarwood, however found that the value of casein Bordeaux was only slightly better than that of

plain Bordeaux in respect to its capacity to withstand washing.

The evaluation of the efficiency of the adhesives added to Bordeaux mixtures, based on copper retention is fraught with difficulties owing to the interference of other factors. As Martin (17) says, "The actual retention of the copper precipitate upon the foliage is not solely dependent upon the adhesiveness of the precipitate, for, after spraying, the solvent action of rain and dew will form a second factor in its disappearance."

The experiments on the effect of spreaders in the field described above have been carried out during only one year which is too short a time for the obtaining of definite results. They are being continued.

Effect on leaf retention.

The final criterion of the value of modification in mixing methods or of additions of various materials as adhesives and spreaders must be their effect in increasing disease control as manifested by crop yields. The difficulties of establishing significant crop differences in field experiments when the differences are certain to be relatively small are too well-known for further comment. In view of this an attempt has been made during the last three years to obtain evidence by the technique of sampling the leaf amount in experimental plots as to the retention of leaf. This method is a direct means of estimating the efficiency of a spray in preventing leaf fall which is caused at least until November almost entirely by the activities of Leaf Disease. In the area under experiment Black Rot does not occur so that it is the effect of the spray in controlling Leaf Disease which is alone involved.

The results for various Bordeaux mixtures are given in the table, together with a calculation of the percentage infection per each set of 60 branch systems.

TABLE 7.—*Giving Leaf Count and Percentage Infection Data for Different Spray Mixtures.*

	1930		1931		1932	
		per cent		per cent		per cent
Linseed Oil Bordeaux	6·35±·21	29·3	6·23±·23	26·8	5·93±·21	14·1
Casein Bordeaux ...	5·90±·18	26·2	6·19±·24	26·1	5·84±·17	10·4
Resin Soda Bordeaux.	5·50±·16	32·1	5·94±·20	30·3	5.94±·21	14·1
Plain Bordeaux ...	...	...	5·40±·19	42·7	5·60±·17	9·5
Check no Spray ...	2·40±·13	49·4	3·13±·17	72·5	4·27±·23	75·7

Observations were also made in all three years on alum Bordeaux, and two Burgundy sprays. These will be dealt with in other sections. Observations on two linseed oil Bordeaux mixtures containing twenty and forty ozs. of oil were made in 1930 and 1931, but were dropped in 1932 as they showed no advantage over the ten oz. strength. Observations on Solbar, a German proprietary material were carried out in 1930 and 1931, but this was also dropped as it showed itself markedly inferior to Bordeaux.

So far the data obtained do not reveal any significant difference between the different adhesives that have been recommended except in the case of resin Bordeaux and linseed Bordeaux in the first year's observation. In this case the difference in leaf amount is definitely significant. It may be noted from an examination of the data for the control observation that the attack of Leaf Disease was more severe than in the other two years and that differences in effectiveness were likely to be exaggerated.

Turning to the data for plain Bordeaux, for which two years observations are available, the differences between it and the various Bordeaux plus adhesive mixtures are significant in 1931, except possibly in the case of resin Bordeaux. In 1932, on the other hand, the differences are not significant in any case. The latter year was apparently less favourable for Leaf Disease than 1931, as shown by the figures for the control plots.

These data suggest that the use of an adhesive is desirable although in years less favourable to the disease, it may not cause any significant difference in the amount of control. The information available in this study cannot be said to throw very much light on the respective value of the three adhesives tested. On these figures alone, no definite conclusion is possible so that the selection must be made for the present on consideration of cost and ease of preparation, rather than on any definite proof of superiority. These considerations would lead, in the first place to the rejection of resin soda on account of its rather troublesome preparation. The choice then rests between linseed oil and casein, and the basis of choice can only be cost and convenience.

Linseed oil is convenient in that it is simply poured into the mixture and thoroughly stirred in. It requires care, however, in cleaning out sprayers after use, as oxidation of the oil on strainers and in nozzles may give rise

to clogging, and the dried film is extremely difficult to remove. Casein requires a little more attention in mixing, but is free from any clogging effects. The price of both materials varies from time to time, but recent figures show that the cost per acre for these two adhesives is at present about the same.

A word may be said of the crop yield of the plots from which leaf counts were obtained. At present only two years crop figures are available, as during 1930, these sprays had little effects in determining yields. The yields obtained cannot be utilised for deciding the relative value of the different sprays until more records are available, but the data are in general agreement with the leaf count results. These actual yields will be found in Table 18.

The Function of an "Adhesive."

It has been usual to speak of the additions to Bordeaux dealt with in the preceding sections, as adhesives, but it is not clear whether their action is merely adhesive, or whether they act mainly or partly as spreaders. The rather indefinite results of the copper analysis on glass plates and the lack of any correspondence with the field leaf count data suggested that possibly the function was more in assuring an even film of copper containing particles than in increasing adhesion.

This is supported by the fact that with experience the Bordeaux coating on leaves produced by spraying with say casein Bordeaux can be distinguished by the eye from that produced by plain Bordeaux owing to differences in evenness. A further supporting fact is the more marked influence of "Adhesives" on rate of settling though the results with resin in these experiments are not supported by field data. At the same time, resin does give an evenly coated appearance to leaves with Bordeaux mixture containing it (Figure 3).

It must be admitted that the results of the studies of adhesives and spreaders made in connection with this work are extremely difficult to interpret. It seems that some of the claims previously made for adhesives and spreaders require more adequate experimental confirmation than is at present available. As stated it is proposed to continue experiments in this connection using the method of copper analysis on leaf samples collected in the field. The result so far obtained are distinctly promising

and warrant the hope that more definite results will be obtained through a continuation of the experiments.

A further line of investigation was recently taken up on the Coffee Experimental Station, Balehonnur. This is the study of the spreading qualities of cheap local vegetable oils added to Bordeaux mixture. It was long ago found by Bedford and Pickering (4) that the finely divided basic precipitate of Bordeaux mixture, emulsifies vegetable oils. Recently the investigations of Martin and Salmon (19) showed that vegetable oils emulsified with Bordeaux mixture, lead to very good spreading qualities and result in rapid fungicidal action on powdery mildew of hops. This property of vegetable oils as spreaders has recently been taken up for investigation with reference to coffee spraying. The oils at present under test are groundnut oil, sesame oil and honge oil (obtained from seeds of Pongamia glabra).

Burgundy and other Copper containing Mixtures.

Although Bordeaux has been generally advised for spraying coffee, a number of planters more especially outside Mysore State, have used Burgundy mixture. This mixture is essentially similar to Bordeaux differing only in that, the insoluble copper containing fungicidal particles are obtained by using soda with copper sulphate in place of lime. The composition of the standard mixture is as follows:—

1. Five pounds of copper sulphate are dissolved in five gallons of water.
2. Two and three-fourths pounds of soda ash are dissolved in 45 gallons of water.
3. Solution one is poured into solution two and stirred. The result of mixing is a sky blue flocculent precipitate, which must not be allowed to settle out.

It can be seen that the rules of mixing for Bordeaux apply equally to Burgundy. The mixture should always be made up by adding strong copper sulphate solution to weak soda solution and never *vice versa*. The Burgundy may have the usual adhesives added to it, but the two which have been most frequently used are resin soda of the same composition as that used with Bordeaux and fish oil resin soap at the rate of one to two lbs. per 50 gallons.

The only real advantage in the use of Burgundy is that soda ash is a purer article of commerce than quick-lime,

is less subject to rapid deterioration and is more readily soluble in water. Moreover there is an economy in transport owing to the smaller quantity required for every pound of copper sulphate.

Its disadvantages lie in lack of visibility on the leaves making supervision more difficult, and in the fact that excess of soda is more dangerous than excess of lime, so that the preparation of the mixture requires more careful control. Instances have come to our notice recently indicating that this danger may be a very real one.

The question arises as to its efficiency when compared with Bordeaux. In the experiments with different adhesives and different types of spray, two Burgundy sprays have been included for three years, while a third was added in 1932. These have been studied by the leaf count method described above and are given in Table 8.

TABLE 8—*Giving Leaf Count and Percentage Infection Data for Bordeaux and Burgundy Mixtures.*

	1930		1931		1932	
		Per cent		Per cent		Per cent
Fish Oil Resin Soap Burgundy.	5·57±·23	30·7	5·66±·26	32·6	5·99±·24	22·3
Resin Soda Burgundy	4·87±·24	31·9	5·97±·21	42·7	6·06±·22	21·7
Plain Burgundy ...	...	...	...	...	6 32±·21	19·6
Casein Bordeaux ...	5·90±·18	26·2	6·19±·24	26·1	5·84±·17	10·4

In no case is there a significant difference in leaf amount except in the case of the first year's data for resin soda Burgundy and as far as these observations are concerned there is no reason to suspect any great difference in efficiency. No satisfactory explanation can be given of the poor results with resin soda in 1930, but as resin Bordeaux did poorly in that year, it is possible that something may have been wrong with the adhesive. A consideration of the data for percentage infection shows a tendency towards rather higher percentages of diseased leaves with the Burgundy sprays. This is especially the case with resin soda Burgundy in 1931, and with all three Burgundy sprays in 1932. This must be regarded as evidence in favour of Bordeaux mixture and is supported by the crop yield data (see Table 18) which reveal rather marked evidence of a lower efficiency of Burgundy mixture. These crop data are for two years only and it is desirable to await further years' figures, but the indications

from percentage infection and from crop yield do not favour the use of Burgundy.

It is difficult to give accurate data on comparative costs owing to the fluctuations in market prices of ingredients. Using figures given in the Coffee Experimental Station Report for 1930 and 1931, the comparative cost of a full strength mixture are as follows, excluding the adhesives:—

Bordeaux	..	5-5-50	Rs. 12-6-0 per acre.
Burgundy	..	5-2¾-50	„ 12-1-0 „

It must be understood that these figures are purely comparative and not to be taken as necessarily the actual costs of the mixture in practice.

If fish oil soap is used as an adhesive, the mixture will cost more than Bordeaux with casein. Unfortunately no data are available for the use of casein with Burgundy.

Ashplant (2) was of the opinion that Burgundy benefitted less from the addition of adhesives than Bordeaux but his evidence was based almost entirely on settling experiments, the results of which cannot be accepted as final with regard to behaviour in the field.

The problem of whether Burgundy can be reduced to a half strength of 2½-1⅞—50 has not been investigated by us. One report in Capt. Windle's *Modern Coffee Planting* (38) expresses satisfaction with the lower strength, as a result of one season's working. This question requires further study, but the less favourable results suggested by percentage infection and crop yields do not hold out promise that results will be as satisfactory with reduced strength.

It does not seem that Burgundy can be recommended as a substitute for Bordeaux and it seems possible that Burgundy users may get better results with Bordeaux.

Of other copper containing mixtures we have experimented with mention must be made of alum Bordeaux. The original idea with which this mixture was employed was to economise in the quantity of copper sulphate used, part of which was replaced by potash alum. This mixture was first tried during 1924 and was found to give

fairly good control against Phytophthora on arecanut (27). The method of preparation is as follows:—

A. To 2 lbs. of copper sulphate dissolved in 12 gallons of water, 2 lbs. of potash alum were added.

B. Two and a half pounds of lime in 12 gallons of water.

Pour A into B stirring slowly. Lime caseinate adhesive was added as usual.

It is not clear in what way the addition of potash alum improves the mixture, since alum by itself has no great fungicidal value. Probably the adhesive properties of the mixture is improved to some extent. Results obtained by Neuweiler (30) led him to believe that the addition of alum increased the efficiency of 1 per cent Bordeaux mixture to equal that of the 2 per cent mixture. Experiments conducted on the Coffee Experimental Station, however, have not given uniformly encouraging results with regard to crop yield, as discussed later in these pages. Experiments have also been started by us with colloidal copper solutions, such as Bouisol, and also one prepared by the Department of Chemistry, Central College. While as yet the experiments have not sufficiently progressed to enable us to find out their efficiency, it may be pointed out that the spray does not show up on the sprayed foliage thus making it difficult for easy recognition during subsequent estate inspection.

It may be mentioned that in East Africa satisfactory control of Leaf Disease has been obtained by spraying with "carbide mixture" prepared as follows:—

Two pounds copper sulphate, 12 oz. calcium carbide, 40 gallons water.

Fungicidal Dusts.

It was thought that by the application of fungicidal dusts the expenditure on labour requirements for carrying water to various parts of the estate for the preparation of the mixture would be avoided. Thus, various dusts imported from America, such as Kolodust, Bordeaux dust, and oxidised sulphur, and one dust Verminite from England and another manufactured by a Bombay Firm, have been tried.

It has been found that these dusts do not properly adhere to the under surface of the coffee leaf, and they, consequently, have been found to be quite ineffective in controlling Leaf Disease.

TABLE 10.—*Studies in Spray Mixture Strength. Percentage Infection.*

	Sept. Observations		Feb. Observations	
	Bordeaux mixtur		Bordeaux mixture	
	1%	·5%	1%	·5%
	Per cent	Per cent	Per cent	Per cent
1930 Guntanaik ...	47·0	48·8	...	...
1931 May and September ...	21·4	37·4	31·7	31·7
1931 May only ...	22·2	28·2	31·7	21·7
1931 September only ...	73·5	70·7	22·3	24·2
1932 May and September ...	51·0	45·7	22·8	32·6
1932 May only ...	19·2	25·1	40·0	38·1
1932 September only ...	79·8	71·3	24·8	33·0

The February observations are more difficult to interpret as the situation is complicated by the influence of the crop yield on leaf fall. This influence may be the reason for the significantly lower leaf amount in the ·5 per cent twice sprayed area in 1931, especially as in 1932 the position is reversed. In the case of the September sprayed plots the difference between the two treatments is again quite insignificant.

The pair of experiments conducted in May only, remain for consideration and in this case, there is a suggestion that the one per cent sprayed area has shown a slightly better retention of leaf than the corresponding ·5 per cent sprayed area. In both years the difference shows slight significance.

The figures for percentage infection at this period are rather irregular and do not provide sufficiently definite evidence to upset the conclusions derived from the leaf count.

It may be concluded that in general the half strength ·5 per cent mixture can give as satisfactory control as the full strength one per cent mixture. It is clear, however, from the February observations on the areas sprayed in May only that the ·5 per cent mixture is very near the lower limit and that when a single spray in May alone is used there may be a falling off in efficiency in the later months after application.

Of course, the ·5 per cent mixture, being near the lowest limits of possible reduction in strength, is likely to

reveal defects in methods of application more readily than the one per cent mixture where there is a considerable margin for variation in efficiency. With efficient application, there seems no reason why the half strength mixture should not give quite as satisfactory results as the full strength. The very considerable saving in cost of materials is well worth the extra care in supervision.

Time of Spraying.

The problem of the time at which spray applications should be made depends on three main factors :—

(1) The mode in which the spraying mixture acts.
(2) The time of activity of the disease.
(3) The time when the greatest susceptible area, *i.e.*, leaf area is present on the tree.

It must be made clear at the outset of this discussion that Bordeaux spraying is a protective treatment. In no case does it act as a curative one, though with some diseases it may prevent an already established infection from spreading. Once an area of leaf-tissue is attacked and damaged by a fungus disease, no application of fungicide can cure the disease, for leaf tissue in coffee has very little, if any, power of repairing damaged tissue. Since, therefore, Bordeaux mixture can only act as a protective, application should be made before the out break of the disease or diseases becomes serious and also when the largest area of susceptible tissue is present on the trees. Spray applications demand as accurate a knowledge of the seasonal fluctuations of the diseases and of the growth habits of the plant to be protected as can be obtained, as it is upon these that the success or failure of the treatment depends.

In the earlier discussion on the diseases against which spraying is used the subject of the seasonal development of these diseases has already been considered. From this it is clear that, as far as Black Rot is concerned, protection must be provided at some period before the monsoon rains and this period must be determined by the time at which the plants are in the fullest leaf. The position in the case of Leaf Disease in the western coffee districts is not quite so simple since the maximum of this disease is sometimes not reached until October or November, and quite frequently it has not done serious damage before September.

Detailed observations have shown that the time of attainment of the maximum depends to a great degree on the exposure to wind during the monsoon. This was clearly brought out in 1930 when regular observations were made on two areas fairly close together, one exposed to the monsoon wind and the other sheltered from it. The former experienced the maximum of its Leaf Disease attack in November, while the latter attained a maximum in July. Conditions were somewhat exceptional, in that the great difference in the time of the maximum under similar rainfall conditions shows the importance of aspect in determining the time of serious attack.

The results of the observations in the sheltered area indicate quite clearly that a spray before the monsoon is as necessary for the control of Leaf Disease in such areas as it is for Black Rot.

The problem in the windswept area is a little more complex as the question arises as to whether a spray immediately after the monsoon is sufficient to give satisfactory control. An examination of the data obtained for the windswept area shows that by the middle of September, 23·5 per cent of the leaves were infected and the following fortnight showed an increase to 35·1 per cent which would be due to infections occurring during the first fortnight of the month. It can be seen that the rate of spread is extremely rapid at this period and, as spraying can rarely be started before the middle of September, it is clear that the disease will be established before spraying can approach completion. The extent of the attack at this time is marked, in those areas exposed to wind, by the fact that the disease is widely distributed without a concentration on individual leaves leading to extensive leaf fall.

Even if this September spray can be completed by the end of September, ample supplies of spores are available for the infection of new flush, while on the other hand, any attempt to wait for the post monsoon flush of leaf will result in the loss of a large proportion of the older leaf which is so rapidly being infected. It seems that, even with a maximum intensity of attack towards the end of November, the disease is well established by the middle of September, though not to such a degree as to cause severe leaf fall. However, centres of infection are sufficiently numerous to cause the destruction of any new leaf not sprayed immediately on formation.

It seems, therefore, that even where the maximum attack of the disease does not occur until November, adequate control demands a spray before the monsoon.

What is the status of the spray after the monsoon? As has been pointed out in the section on Leaf Disease, conditions favourable to the disease may persist up until December or even longer. Therefore, any new flush produced during the later part of the year is open to infection from the disease pustules always present to some extent on the coffee sprayed before the monsoon. The loss of this young flush results in shoots with their top two or more joints defoliated, and these tips are liable to die back to the youngest pair of spray-protected leaves. Further, new shoot growth initiated after the monsoon is also liable to die back if the new growth received no protection. The spray after the monsoon provides this extra protection of the September growth.

Definite evidence of this effect was obtained in 1930 when it was found, in detailed observations in the sheltered area mentioned above, that the main maximum of the disease in July was followed by a second smaller maximum at the end of November, coinciding with the single maximum in the windswept area. In a parallel area sprayed in September, the second maximum was suppressed, though in the absence of a spray before the monsoon the damage was done by the first maximum and the small protection given the new leaf was of little value.

It appears, therefore, that the September spray must be regarded as of secondary importance, its value being dependent on a spray in the period preceding the south-west monsoon.

It is possible in some areas that the September spray may be omitted without serious loss of protection. This applies especially to districts with a short north-east rainfall and absence of heavy mists in the latter end of the year. In the eastern coffee districts such as the Shevaroys and the Nilgiris, it appears that one spray about July gives sufficient protection.

Having given this general outline of spraying times based on work designed to study the seasonal fluctuations of the disease, attention must now be transferred to the results of the leaf count methods applied to plots sprayed at different times. To simplify the discussion, the data for the plots sprayed with ·5 per cent of the mixture only will be considered, together with their attendant

control plots. These plots are fairly sheltered from the south-west winds but not sufficiently to lay them open to much Black Rot. The results are given in Table 11.

TABLE 11.— *Showing Average Number of Leaves per Shoot on Sprayed and Unsprayed Coffee.*

Leaf counts made	Sept. 1931	Feb. 1932	Sept. 1932	Feb. 1933
1. Control, (no spray) ...	2·38±·19	0·95±·11	4·66±·22	2·52±·14
·5 per cent May and September.	6·17±·19	2·45±·12	6 61±·23	3·80±·16
2. Control	2·94±·19	1·48±·13	5·31±·25	2·50±·12
·5 per cent May only ...	6·82±·20	1·67±·16	6·96±·21	2·25±·13
3. Control	...	1·33±·11	4·68±·23	2·13±·13
·5 per cent September only ...	3·34±·19	2·34±·15	4·03±·19	2·87±·13
4. Control	...	...	3·78±·18	2·66±·11

TABLE 12.—*Giving data on Yield in lbs. of Ripe Cherry per Acre in Time of Spraying Experiments.*

	1931–32.	1932–33.
Control ...	4033	.. 92
·5 per cent May and Sept. ...	4476	... 2156
Control ...	2063	... 369
·5 per cent May only ...	1629	... 2764
Control	1497	.. 919
·5 per cent Sept. only ...	1980	... 2275
Control ...	1647	... 1144

The table requires a certain amount of explanation. Treatments were started in May 1930 but without control plots, these being formed in May 1931, out of the plots under treatment so that the data for the control plots are not strictly comparable in 1931 and even in 1932. Crop yields still show differences imposed by previous history. This is especially the case with the first control which was in 1930, part of the ·5 per cent May and September sprayed block.

The leaf counts reveal immediately the paramount importance of the May application. Both the May sprayed plots bore twice as much leaf as the September sprayed block in 1931. The last does not differ significantly from the second control which received no treatment after May 1930 though it does from the first. The low figures for this plot must be attributed to the severe disease following the abandonment of spraying this plot.

In 1932, the difference between the two plots receiving a May spray and the one receiving a September spray only is less extreme. There is a suggestion that this latter area has a slightly lower leaf amount than some of the control plots. However, little reliance can be placed on this as the differences between control plots themselves, in different parts of the experiment are significant (compare controls 2 and 4.)

Consideration of the February counts reveals definite evidence of the value of the September spray in conjunction with the May spray, the leaf amount in both years being significantly higher in the twice sprayed plots. In view of the remarks made with respect to the use of ·5 per cent strength in May only in the discussion of the strength of mixture, it is necessary also to compare the ·5 per cent strength twice-sprayed block with the 1 per cent strength May sprayed block. The possibility of a greater efficiency of this latter mixture nullifying the difference between ·5 per cent strength in May only and the same mixture in May and September must be examined since one application of 1 per cent strength would be cheaper than two of the ·5 per cent strength. It is found (see Table 9) that in 1931, the difference between the one per cent May spray and the ·5 per cent May and September spray is not significant though it is so in 1932. With regard to the 1931 figures the fact that the ·5 per cent May and September sprayed block bore over twice as much as the 1 per cent May sprayed block (see Table 14.) offers an explanation of the lack of significant difference in leaf amount in favour of the ·5 per cent twice sprayed area. As far as the data go it must be concluded that the two applications at ·5 per cent strength are to be preferred to one application of 1 per cent strength.

The value of a single spray in September does not appear very striking from the data for February leaf counts. In February 1932 it gave leaf amounts significantly higher than the control but in 1933 the difference is less marked, except perhaps in the case of the third control. It certainly gave a slightly higher leaf amount than the May sprayed plot in both years, but this is quite negligible compared with the difference in favour of the May spraying in the September observations.

It must be noted that a much higher proportion of the leaf in both controls and September sprayed plots is newly produced in the October flushing period and this

leaf production involves the utilisation of material which would otherwise go to fruit bud production. Crop yields have not yet been obtained over a long enough period to show the greater benefit of the May spray, but the yield from the May sprayed plot in 1932-33 shows a greater gain over the yields of 1931-32, than does that of the September sprayed plot. This is shown to a still greater degree in the case of the parallel pair of plots sprayed with one per cent mixture (see Table 13).

TABLE 13.—*Yields in lbs. Cherry per acre of Single Sprayed Plots in Time and Strength of Spray Experiments.*

	1931–32.	1932–33.
1 per cent May only	2,070 lbs.	2,813 lbs.
1 per cent Sept. only	1,741 „	1,538 „
·5 per cent May only	1,629 „	2,764 „
·5 per cent Sept. only	1,980 „	2,275 „

It appears that the control exerted by two sprays at ·5 per cent strength is superior to a single spray of either strength in either May or September. Under the condition of this experiment at Balehonnur, moderately sheltered coffee in an area subject to a fairly heavy south-west monsoon and a fairly big north-east monsoon followed by a period of dry weather with heavy morning mists, the May spray is very much more important than the September spray. The crop yields as yet can hardly be expected to show definite results, but they are in agreement with the conclusions derived from the leaf counts. These yields are given in Table 14, the control plots being omitted as separate entries as individually the variation is very high due to the previous treatments already mentioned. The mean of values of six control plots are given to illustrate the differences due to spraying.

TABLE 14.—*Yields of Plots in the Time and Strength of Spray Experiments. Yields in lbs. Cherry per 1,200 trees.*

	1931-32.	1932-33.	Mean.
1 per cent May and September spray	2,995	2,578	2,787
·5 „ „ „	4,476	2,156	3,316
1 „ May spray	2,070	2,813	2,442
·5 „ „	1,629	2,764	2,197
1 „ September spray	1,741	1,538	1,640
·5 „ „	1,980	2,275	2,128
Control unsprayed (mean of 6 plots)	2,058	763	1,411

The data so far considered have supplied evidence as to the periods during which spraying can be effectively applied. It is now necessary to approach the question of time in a little more detail with respect to the most favourable times within the periods before and after the monsoon. It is obvious from what has already been said, that the most favourable period will depend on two factors, the time when the leaf amount is greatest and the time at which the disease begins to become active.

With regard to Black Rot the position is clear. The leaf quantity increases up to the outbreak of the monsoon and the disease does not become active until after the outbreak. It is obvious that the nearer to the monsoon the spraying can be carried out, the greater the number of leaves protected and the greater the control of the disease.

In the case of Leaf Disease, the position is a little different, as the disease begins to increase from the time of the first showers. The question arises as to whether it is more important to stop the first development of the disease, or to allow the disease to develop for a month or six weeks in order to ensure protection of the largest possible area of leaf. A study of the amount of disease developed up to June 15th shows that the percentage of infected leaves is not high. Even in the area where the maximum was attained in the latter part of July, the percentage of infected leaves on June 9th was only about 16 per cent, while in the area where the maximum was delayed until November, it was under five per cent. This suggests that, as a rule, the increase in the pre-monsoon period is quite small, and nothing is to be gained by attempting to control it, if it means leaving any considerable amount of new leaf unprotected.

This is borne out by some data obtained in 1931 and 1932. In the experiment dealing with different types of spray in 1932, it was found that the percentage infection was very considerably lower in the sprayed plots than in 1931, while in the case of the experiment dealing with time and strength of spray, the percentage infection in the one per cent twice sprayed block (corresponding in treatment to the type of spray experiment treatments) was higher in 1932 than in 1931. The two experiments are not far apart and under approximately similar conditions of aspect. The leaf count and percentage infection records for the controls in both sets of experiments indicated

conditions slightly less favourable to the disease in 1932 than in 1931.

The apparent discrepancy in the results can be explained if the dates on which spraying was carried out are considered. The relevant data are tabulated in Table 15.

TABLE 15.—*Effect of Time of Spray on Effectiveness.*

Series A.—*Type of Spray Experiment.*

Date of spray	14th May 1931		3rd June 1932	
	Percentage infection	Leaf amount per branch counted	Percentage infection	Leaf amount per branch counted
	Per cent		Per cent	
Linseed Oil Bordeaux	26·8	6·28	14·1	5·93
Control ...	72·5	3·13	75·5	4·27

Series B.—*Time and Strength of Spray Experiments.*

Date of spray	23rd May 1931		5th May 1932	
	Percentage infection	Leaf amount per branch counted	Percentage infection	Leaf amount per branch counted
	Per cent		Per cent	
Linseed Oil Bordeaux	21·4	6·55	51·0	6·49
Control ...	79·2	3·15	66·4	4·73

In 1931, both sprayings were done within a week or so of one another and the percentage infections are much the same, but in 1932, there is a full month between them and the percentage infections shows a wide difference with the heavier infection in the area sprayed earlier. If

attention is transferred to the same experiment in the two years, Series A shows a lower percentage of disease with the later spray, the one in 1932 being 20 days later than in 1931. This, of course, might be due to the slightly less favourable conditions for the disease in 1932, as shown by the better leaf count in the controls. In the case of Series B, the position does not allow of this explanation as the percentage of disease is higher in the year when the control leaf counts indicate less favourable conditions for the disease. Here the date of spraying was 18 days earlier in 1932, when the percentage of disease is higher. The evidence so far indicates clearly that a late spraying as close to the monsoon as possible is the most satisfactory. It seems clear that it is more important to cover the largest area of the leaf possible, than to try to check the first development of the disease in April and May.

With regard to the application after the monsoon, it is less easy to decide as observational data are lacking. In general, early application as soon as possible after the rains seems to be most satisfactory. It has been noted that where coffee has been sprayed in the pre-monsoon period, the heavy load of leaf carried into September and October considerably reduces the September and October flush, and a spray in late September or early October does not miss a very large amount. If a single post monsoon spray is done in areas where the leaf disease maximum is late it is absolutely necessary to spray early to protect the leaf, carried through the monsoon as it is this leaf which must provide the elaborated material for fruit bud differentiation. If it is left unsprayed the rapid progress of the disease in September will soon destroy a large proportion of this valuable leaf.

A further point against late spraying after the monsoon is that by this time the disease is well established on unprotected leaf, and, if this leaf is then protected sufficiently to prevent its falling, it is liable to remain on the tree through the dry weather and afford active centres of further infection after the first showers. In fact there is a tendency for all sprayed coffee to carry more infected leaf through the dry weather than unsprayed. This is illustrated by the data for February in the time and strength of spray experiment, where the retention of diseased leaf is even more marked in the twice sprayed and May sprayed plots than it is in the September sprayed plots. These are given in Table 16.

TABLE 16.—*Giving Date on Percentage of Infection in February.*

	1931. Per cent	1932. Per cent
1 per cent May and September Spray ..	31·7	22·8
Control	14·9	20·7
1 per cent May Spray	31·7	40·0
Control	12·7	18·1
·5 per cent May and September Spray ..	31·7	32·6
Control	10·4	26·0
·5 per cent May Spray	21·7	38·1
Control	14·8	24·4
1 per cent September Spray ..	22·3	24·8
Control	22·3	31·1
·5 per cent September Spray ..	24·2	33·0

On the whole, it can be seen that the sprayed plots carry a higher percentage of diseased leaf than the unsprayed. If the absolute amount of diseased leaves is considered the difference is even greater since the unsprayed plots carry less leaf.

This affords an explanation of the fact frequently observed, that areas sprayed in one year and then left unsprayed suffer very severely in the latter year, much more severely than parallel areas which were sprayed in neither year. Sprayed areas carry over a much greater amount of leaf than unsprayed areas and while the number of disease pustules per leaf may be much smaller in the former case, the total number of disease pustules per tree will be larger. This leads to a more rapid increase of the disease after the early spraying showers. This must be regarded as a temporary matter which will right itself in the following years. Of course, if spraying programmes are kept up the problem does not arise in a serious form as the increase in the disease is met and checked by the next spray.

In concluding this section the evidence may be summarised in the following terms. In western coffee districts, two sprays, one as close to the monsoon as possible and the second as soon after as possible, give the best results. Of the two applications, the first one before the monsoon is the more important, as it gives quite good results alone and in some districts may be sufficient in most seasons. The spray after the monsoon appears to be of relatively little use alone, though crop yields over the controls in 1932 indicate a profitable increase with this spray alone (See Table 14).

From a practical point of view it may be suggested that areas sprayed early before the monsoon should be taken up first after the monsoon, and that areas producing a heavy flush of wood in April-May should be sprayed last before the monsoon, and areas with small growth at this period sprayed earlier, as where new wood growth is small, the losses from an early spray are likely to be less severe.

The Results of Spraying.

In connection with the discussion of adhesives on strength of mixture and time of application, a considerable body of evidence has been produced showing the striking effects of spraying on the amount of leaf carried through the period of activity of the disease, and on the percentage of leaf infected. In addition, some evidence of the increase in yield has been given, but this has taken secondary position in evaluating results. From a technical point of view, the data derived from leaf count and percentage infection are more suitable for comparing different treatments than crop yields, as a large number of complicating factors are avoided. Crop yields present great difficulties of interpretation especially when data are available only over a few years, when the differences to be studied are bound to be slight. The present section is to be devoted to a consideration of the effect of spraying on yield and comparisons made between sprayed and unsprayed areas. None of these data is susceptible as yet of a satisfactory statistical treatment, but the differences between sprayed and unsprayed areas are so great as to leave no doubt of the significance of the results.

The first available data on yield are those of Munro at Siddapur, which cover the year 1920-21 to 1927-28. These are given in Table 17.

TABLE 17.—*Showing Yield during eight years in Spraying Experiments at Siddapur.*

Plot	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28
23-A ...	4,541	1,844	3,048	10,965	1,328	2,897	7,960	4,800
23-B ...	1,857	3,853	1,480	8,380	2,160	2,359	8,164	5,760
24-A ...	3,848	1,891	2,676	3,527	5,379	656	7,784	960
24-B ...	1,738	1,178	1,938	3,299	1,828	1,289	6,144	720

Mean yield of the Plots.

Plot	Mean for 8 years	Mean for 6 years	Treatment	Area of plot
23-A ...	4,673	5,166	Spray once in May ...	1/8 acre
23-B ...	4,252	4,884	Spray twice, May and Sept.	1/8 acre
24-A ...	3,340	3,497	Unsprayed	1/8 acre
24-B ...	2,268	2,538	Unsprayed	1/8 acre

The data given include the calculated mean yield for each plot for the whole period and for the years from 1922-23 omitting the first two years. It is clear that the evaluation of the results is difficult seeing that the differences between the control plots themselves are so large, judging by the data for the first two years, the three plots 23-A, 23-B, and 24-A are fairly similar, so attention will be restricted to these.

There is little difference between 23-A and 23-B which suggests that at Siddapur, the second spray is of little or no importance. It may be noted in this regard that Siddapur experiences a smaller north-east monsoon than Balehonnur.

The average increase of 23-B over 24-A for 1922-23, is 1,387 lbs. of ripe cherry per acre per annum, an increase of nearly 40 per cent. Calculating that ripe cherry gives about 20 per cent clean coffee, the average annual increase due to spraying is 277 lbs. or about half a candy (560 lbs.). Estimating the value of a candy of dry cherry at Rs. 200, this increase represents a return of Rs. 100 per acre. Munro estimated the cost of spraying twice at Rs. 60-8-0 in 1923-24 and even at this extremely high estimate, the treatment shows a substantial profit. A single spray will, of course, cost proportionately less, and at Siddapur gave equally satisfactory results.

The Balehonnur data only cover two year's yields. For convenience and to simplify discussion, the results from the experiments on different types of spray are grouped in three classes, one per cent Bordeaux spray, one per cent Burgundy spray, alum Bordeaux spray and control unsprayed plots.

TABLE 18.—*Showing Yields in Plots Sprayed with Bordeaux and Burgundy mixtures at Balehonnur.*

Type of spray		No. of plots	Lbs. cherry per 1,200 trees 1931-32	1932-33
One per cent Bordeaux.	Casein ...	3 plots	...	...
	Resin Soda ...	3 ,,	...	...
	Linseed 10 ozs. ...	3 ,,	2617 lbs.	2,960 lbs.
	No adhesive ...	3 ,,	...	...
One per cent Burgundy.	Resin ...	3 ,,	...	...
	Fish oil Resin Soap ...	3 ,,	1,962 lbs.	2,020 lbs.
Alum Bordeaux		3 ,,	2,757 lbs.	1,756 lbs.
Control		11 ,,	1,119 ,,	878 ,,

The results are still more striking than the Siddapur figures. It is true, yields of ripe cherry are lower than in the latter experiments, but the differences between sprayed and unsprayed plots represent increases in crop of between 150 and 200 per cent over the controls with Bordeaux and about 100 per cent with Burgundy and alum Bordeaux. The last mixture which showed excellent promise in 1931-32, was less satisfactory in 1932-33. Its low copper content and the addition of alum suggested it originally as a cheaper substitute for the ordinary 1 per cent Bordeaux. The successful results with ·5 per cent Bordeaux discussed elsewhere, tend to render the mixture less promising as the economy in cost with ·5 per cent Bordeaux is greater than with alum mixture. The crop yield data from the time and strength of spray experiment have already been considered in connection with the problem for which the experiment was designed. The results, in spite of the difficulties of interpretation owing to previous treatment and to the large size of the plots and the heterogeneity of the area are equally striking.

At Balehonnur, the results of spraying show increases of 100 per cent and more over corresponding control or unsprayed areas. Of course, increases as large as this will not be obtained everywhere, as the results must depend mainly on the severity of disease attacks in the areas sprayed. We have heard it stated in the district where Balehonnur is situated that estate yields had been doubled by spraying where the disease situation is severe, therefore it seems that increases of 100 per cent are by no means impossible. Such increases mean, at a low estimate an addition of 1½ to 2 cwt. of coffee per acre.

Even taking the value of 1 cwt. of coffee at Rs. 45, this increase represents a very considerable return for the Rs. 25 or 30 required for spraying twice per annum. Estate data are difficult to interpret in the absence of control plots, but planters have repeatedly reported increases up to 2 cwts. per acre and over.

Very interesting data with regard to the results of spraying on private estates were made available to us, owing to the courtesy of planters who readily furnished us with figures of crop yields. As these planters did not keep unsprayed control plots for comparison we have had to follow the course of comparing average yields for the period during which spraying has been carried out with those of a similar period immediately before the commencement of spraying. As certain of those who have furnished figures have expressed a desire that their names should not be mentioned, only the district in which the estate is situated is given. Enquiries were made as to whether any of the reported increase could be attributed to better manuring and in only one case could this be looked upon as in any way contributing.

TABLE 19.—*Showing Average Yield on Private Estates prior to and after Spraying.*

No.	Estate situated in	Elevation	Rain fall	Yield per acre before spraying	Yield per acre after spraying	Average for	Percentage increase
				Cwts.	Cwts.	Years	Per cent
1	Hassan ...	2800-3200	65-80	2	4·8	4	120
2	Biligiririangans ...	4500-5500	80″	4·4	6·5	4	47·7
3	Baba Budans ...	3600-3850	80″	3·3	5·5	5	66·6
4	Baba Budans A. ...	3400	60″	2½	4½	5	85·7
	B. ...	3800	60″	5	5·4		8
5	Nilgiris ...	,,	,,	2-2½	4·5	2	100
6	Nilgiris A. ...	4000	Average	3·24	5·4	3	66·6
	B. ...	4500	71·8	4·32	6·04		39·8
	C. ...	5000		4·8	10·53		119·4
7	Shevaroys A. ...	3500-3800	...	1·5	5·6	7	273
	B. ...	4000-4300	...	0·92	4·72		413

NOTE.—In the case of 4 and 6 above the estates have been divided into blocks according to elevation. Under 7 A and B refer to two different estates.

It will be seen from the figures in the Table, that in many instances the percentage increase of crop, as a result of spraying has varied from 40 per cent to 120 per cent. It is quite probable that this variation may be due

to factors often met with when spraying large blocks such as interference by rain during spraying, or uneven application of the spray. However, it is clearly indicated that there has been a marked increase of crop, except in one instance (No. 4B in Table). It is of considerable interest to note that in this block situated at an elevation of 3,800 feet, the crop on the sprayed area has increased on an average only 0·4 cwt. per acre. On the basis of this experience, the owner of this estate raised the extremely interesting point whether spraying pays in estates situated at higher altitudes. A comparison with the figures of one estate on the Nilgiris (No. 5) is interesting in this connection. Detailed information about the various sprayed blocks has been kindly placed at our disposal by the planter. In all, three blocks have been sprayed, and the figures as tabulated according to the elevation, are presented in the table. It will be seen that at an elevation of 5,000 feet, though the average yield before spraying was as high as 4·8 cwts. per acre, the percentage increase of crop, after spraying has been taken up, has been exceptionally high.

It may, however, be seen that in No. 4, the average yield of the crop even before spraying has been above the average being 5 cwts. per acre. It seems probable that where the average yields of unsprayed coffee are at present as high as this, the increase of crop due to spraying will not be so striking as where the average yields have been lower.

Of course, where Black Rot is severe gains may be even greater, but both the Siddapur and Balehonnur data apply almost entirely to Leaf Disease control since in neither area is Block Rot severe. This widens the economic scope of spraying immensely, for while many have been convinced of the value of spraying against Black Rot, numbers have been sceptical of the results against Leaf Disease. It is admitted that control of the latter is less efficient than that of the former, because Leaf Disease is a much more difficult disease to control but the results given above show that even this incomplete control is usually a very sound economic proposition.

Spraying Machinery, Costs, etc.

Now that it has been shown that spraying is effective in controlling most of the important coffee diseases in

South India, it remains to be considered how best the spray can be applied if the work is to be done efficiently and rapidly. As important as the question of the right kind of spray and the right time of application is the question of the type of machinery to be used. To a large extent this depends on the area that is to be sprayed. Of the Knapsack types, the one gallon Pneumatic Holder sprayers were introduced as far back as 1909, as the most suitable ones for spraying arecanut palms, which involves climbing up the tree. It is computed that over 5,600 sprayers of this type have been imported into the arecanut areas of Mysore, and about 400 sprayers in those of Kanara District.

Various types of spraying machinery have been tested on the Coffee Experimental Station, Balehonnur, with regard to their efficiency and working costs. At the outset a description of the different types is given below with observations on their advantages and disadvantages.

Holder Two Gallon Sprayer.

This consists of an air-tight copper vessel into which, through an opening on one side two gallons of the mixture is poured which fills it to two-thirds full (Fig. 10). The cover for the opening is then put on and screwed tight. Air is then pumped by means of the pump at the top, which is provided with a handle, till the pointer on the gauge shows 5 atm. By turning the stop cock, the fluid is forced out through the nozzle in the form of a fine mist. A length of 4-5 feet of hose with a three feet brass spray rod is all that is necessary. The sprayer is strapped on the back of the coolie and carried into coffee.

Though this type of sprayer is admirably suited for spraying on small estates, there are certain disadvantages attending its use for spraying large estates. The repeated operations involved in charging the sprayer, *viz.*, unscrewing the lid, filling the sprayer, screwing on the lid and pumping, waste a lot of time. Moreover, there is a gradual falling off of pressure and towards the end the spray tends to become coarse with a tendency to form droplets and to run off the surface of the leaf. Also owing to the frequent moving of the coolies with the sprayers up and down the rows of coffee for re-charging the sprayers, some amount of damage results to the crop and branches owing to the brushing action.

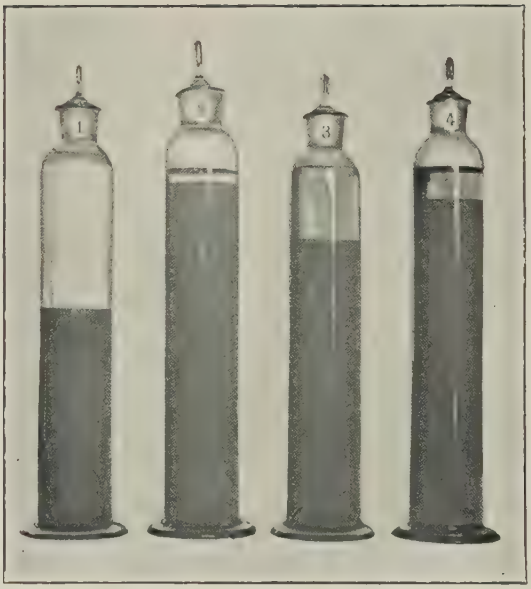


FIG. 4.

Bordeaux mixture in cylinders to show the effect of addition of jaggery on rate of settling. Photo taken 2 hours after preparation. 1. Plain Bordeaux. 2. Bordeaux with 0·1% jaggery. 3. Casein Bordeaux. 4. Casein Bordeaux with 0·1% jaggery.

FIG. 5.

Charging a Battery sprayer (Holder Fix. No. 1) with the mixture contained in the barrel.

Holder Battery Sprayer.

Another Knapsack type which has been tested on the Coffee Experiment Station is the battery sprayer. This consists of a set of six sprayers, and a separate charging apparatus for pumping air and spray mixture. The charging pump is portable, and when required for work, is mounted on top of the receptacle holding the mixture. The sprayer is first charged with air through a valve at its bottom, to a pressure of 5 kg. or 60 lbs. per square inch. Then the spray mixture is pumped into it up to a total pressure of 140 lbs. per square inch. The sprayer holds nearly four gallons of mixture. An emergency valve regulates the amount of air and mixture in the sprayer. This type of sprayer is no doubt the best among the Knapsack type, as it gives a very fine spray and as the pressure towards the end falls off only to a slight extent, but many disadvantages have been found attending its use. Charging the sprayers involves considerable labour and waste of time, as the labourer has to walk up to the pumping apparatus to get the sprayer charged. While this can be relieved to a great extent by keeping spare sprayers, and supplying charged ones to the labourers inside the coffee, the extra labour and outlay do not tend to economise the working costs. The heavy weight of the sprayer, which when charged with the solution, weighs nearly 65 lbs. is not conducive for the carrying on of rapid spraying work. Smaller containers could no doubt be obtained, but this has not been done as other types of spraying apparatus appear to be more suitable for coffee spraying. In addition, this spray outfit requires almost the same number of coolies to operate, as the D. S. P. Headland sprayer, described later, but does less work. Fig. 5 shows the method of charging the battery sprayers.

"Solo" Knapsack Sprayer.

This type has not been given any extended trial on the Coffee Experiment Station. However, mention is made here as some of the coffee planters have been found using it. In this type, the Knapsack only holds the mixture. The pumping arrangement is contained in two brass tubes telescoped one into the other. By manipulating these with the hands with an inward and outward motion, the mixture is drawn in through the bottom tube

and ejected out of the nozzle in a fine spray. The continuity and fineness of the spray vary in proportion to the length and frequency of the stroke.

As the pumping apparatus and spray lance are combined in one, the labourer is not able to wield the spray lance deftly, and consequently the spray cannot be uniformly applied. Moreover, since the labourer has to keep on pumping, he gets tired soon. In our opinion, this type of sprayer is not well suited for spraying coffee.

Hose Types of Sprayers.

In these types of sprayers, the coolies who do the spraying, have nothing to do with the pumping operation. The bulk to be carried by them into coffee is very little being only the hose and nozzle. The time taken up for filling and charging the sprayers, as in the Knapsack types, is eliminated. A uniform good quality spray is obtained as the pressure can be kept more constant than is the case with the pneumatic sprayers. Large scale spraying can easily be carried out only by means of sprayers of the hose type.

Hose types of sprayers worked by manual power.

Among such sprayers, a type which has been found to be efficient in work is the Drake and Fletcher Headland sprayer made by Messrs. Drake and Fletcher Maidstone, England, or the D. S. P. Sprayer, as it is usually called. The machine is strongly constructed and is obtainable mounted either on a trolley or platform. It is worked by two coolies at the pump and is capable of attaining a pressure of 200 lbs. per square inch. A large cylindrical air chamber made of brass, with a pressure gauge fitted on top, ensures uniform pressure. The construction of the plunger pistons, which operate in packed glands, is such that they are easily adjustable, as seen especially where the asbestos packing has to be renewed when leakage of the mixture occurs through the sides of the plungers. The outfit has two delivery outlets, (Fig. 6) each fitted with a stopcock. Owing to its simple mechanism and easy portability, this type of sprayers is very suitable for coffee estates in general. One of us, (Mr. K. H. Sreenivasan, has recently adapted the D. S. P. sprayer to take four lines of hose. A gun metal Y connection is screwed on to each of the stop taps of the machine, and a hose attached to

each of the arms of the Y connection. Another cheap device would be to use a galvanised water pipe T connection with screwed bits attached to the two ends of the arm for fixing the hoses. The lower end of the T connection is screwed on to the stop tap. The obvious advantage of this adaptation lies in the capacity of the machine to cover nearly double the area of what it can do with only two lines hose. When used with four lines of hose, three men are required at the pump instead of the two ordinarily used. Fig. 8 shows a D. S. P. sprayer in use with four lines of hose.

Vermorel Headland Sprayer.

Another type of double suction pump which has been tested on the Coffee Experiment Station is the Vermorel Headland Sprayer supplied by Messrs. Cooper, Pegler, & Co. Although it is designed to take two hoses and spray under fairly high pressure, it does not give an output of work equal to that of a D. S. P. Headland. It is a very handy, neat little machine fairly well suited to smaller estates but owing to a defect in the construction of the plunger pistons, which are made somewhat similar to the plungers of a motor tyre pump, leakage of mixture through the sides of the plunger is a recurring feature which wastes not only a lot of mixture but also time in remedying it. If the pistons are made on the pattern of the D. S. P. with gland nut arrangement to take up the leakage, this will admirably suit small estates where now hand sprayers are in vogue.

Power Sprayers.

One advantage of a motor sprayer lies in the fact that where there is labour scarcity the use of a motor driven sprayer will lead to a considerable saving in men. It will also lead to a more constant pressure and therefore a more uniform type of spray than is possible where manual power is used. Besides these, a slight reduction in the cost of spraying may be possible. One Motor sprayer with four lines of hose will have a daily output equal approximately to that of two D. S. P. sprayers. Where six lines of hose are used, the output should be that of three D. S. P. sprayers but definite figures are not available as yet in this connection.

On the Coffee Experiment Station where considerable attention is being paid to test various types of spraying machinery, three types of motor sprayers have been tested, *viz.*, the Holder Power sprayer, the Vermorel power sprayer, and the New Drake and Fletcher Motor sprayer. The power sprayer manufactured by Gebruder Holder, Germany, has been found to be a useful type for spraying large estates (Fig. 7). This sprayer is provided with a two-cylinder pump geared direct to the engine. The cylinders are horizontal and this together with the rather soft character of the material used in the pistons lead to heavy scouring with consequent leakage of the mixture. The manufacturers, at the suggestion of the Department, have replaced these pistons by hollow steel ones which have proved eminently satisfactory. Absolutely no scouring is evident after two years working.

As originally designed with the container and the engine mounted on two wheels, the outfit was rather too cumbrous to be moved through the estate. Following the suggestions given by the Department, the Firm has designed a lighter outfit with six lines of hose (the original one having only four) giving a uniform spray. This power sprayer is found admirably suited for coffee spraying. Its simple mechanism combined with its light weight and easy portability along estate roads makes it a very suitable and efficient spray machine.

However, in the latest Holder sprayer (6 hoses) imported for a planter, the engine cranking arrangement is rather peculiar. The engine is cranked by means of winding a strong canvas belt round the fly wheel hub and a vigorous pull given, which causes the fly wheel to rotate. A cranking handle such as is used on the model originally imported is preferable to this arrangement.

The spraying lances as now sent out are short and are provided with a handle. The hose is connected to the spray rod at right angles. This arrangement is not suited to our conditions nor do the coolies appreciate it. Hence, a handle is not necessary. If the hose connection is given to the spray rod in a direct line, it will facilitate handling of the rod efficiently. The spray rods should be at least three feet in length. The nozzle discs and stop tap wear out too rapidly and hence it is necessary that these should be made of steel centred bronze. It seems desirable to have separate discs made entirely of one strong metal steel, to avoid unequal wear in the parts.

FIG. 6.

Drake and Fletcher Headland sprayer in action with two lines of hose.

FIG. 7.

Holder Motor Sprayer with four hose attachment.

FIG. 8.

Drake and Fletcher Headland sprayer in action adopted for taking four lines of hose.

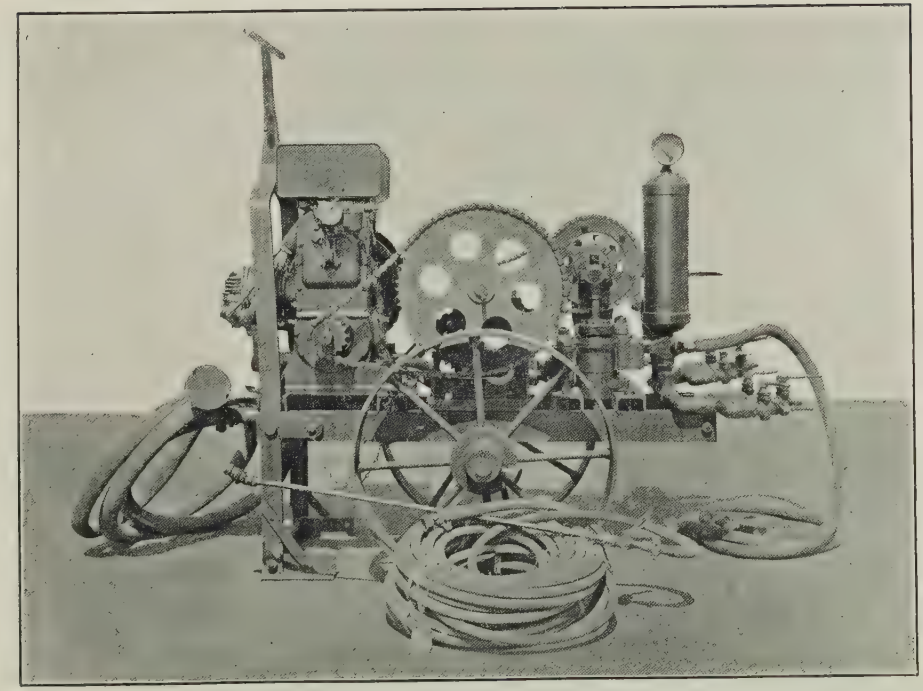


FIG. 9.

Drake and Fletcher's New Power sprayer, with six leads for hose attachment.

FIG 10.

Holder two-gallon sprayer.

Vermorel Power Sprayer.

This sprayer is powered with a 3 H. P. water-cooled engine. The double cylinder pump and the engine are mounted on a trolley. The pistons act horizontally and opposed to one another. It is designed to take four hoses. The outfit is very heavy and is quite broad and hence does not admit free movement on estate roads. Therefore, in its present form, it is not suitable for spraying coffee.

New Drake and Fletcher Power Sprayer.

Recently the above type of sprayer manufactured by Messrs. Drake and Fletcher has been imported and tested on the Coffee Experiment Station (Fig. 9). A 2 H. P. Petter air cooled engine is geared to the vertical acting twin pump with chain drive. The machine works satisfactorily and gives a fine and uniform spray even at a pressure between 140-160 lbs. per square inch. It is capable of attaining a still higher pressure. This outfit is designed to spray with six lines of hose. It is capable of doing 3½ to 4 acres or even more in a day. The petrol and oil consumption is less than that of Holder power sprayer (4 hoses). For spraying about 1500 gallons it consumes about a gallon of petrol and 4 ozs. of lubricating oil, as compared to nearly 2 gallons petrol and about 45 ozs. of lubricating oil consumed by the Holder Power sprayer. Therefore, the working costs with this sprayer are decidedly lower.

The main drawback is its heavy weight. It weighs nearly double that of the latest Holder Power sprayer. In estates where road conditions are not good or where steep pieces have to be negotiated, the heavy weight of the sprayer is a serious drawback. The chain drive is certainly not so neat as the gear drive of the Holder Motor sprayer and with the slackening of the chains, will require adjustment which is of course provided for. It is too early to say whether this is likely to prove a serious drawback.

Output of work of different hose type sprayers.

In evaluating the amount of work turned out per day, by these various sprayers one has to take into consideration, the variable number of lines of hoses in the different kinds of sprayers, the Headland Sprayer having two, the Holder Power sprayer four, the Drake and Fletcher Power

sprayer having six lines of hose, so that the work turned out cannot be said to be really comparable. The discharge per line of hose has been calculated as follows:—Power sprayer with six hoses 6-7 barrels; with 4 hoses 5-6, and with the D. S. P. Headland with two hoses 5-6 barrels of mixture for each hose per day. Further the size of the nozzle disc and the pressure at which the sprayer is worked determine the quantity of mixture discharged during a given time, as will be seen in the following table.

An experiment was conducted with the Holder Power sprayer and the D. S. P. Headland sprayer to determine the quantity of the mixture ejected out per minute using Drake and Fletcher's No. 1 and No. 2 nozzle discs and worked at 120 and 150 lbs. pressure per square inch.

TABLE No. 20.—*Showing rate of Spray discharge, as influenced by Nozzle Size and Pressure.*

Kind of sprayer	Nozzle size	Time taken to discharge 40 gallons of mixture		Liquid ejected by each nozzle per minute	
		120 lbs. Pressure	150 lbs. Pressure	120 lbs. Pressure	150 lbs. Pressure
D. S. P. sprayer with 2 hoses.	No. 1	40 minutes	37 minutes	80 ozs.	86·5 ozs.
	No. 2	22⅛ ,,	19⅜ ,,	142 ,,	162 ,,
Holder Power sprayer with 4 hoses.	No. 1	19⅛ ,,	17¼ ,,	83 ,,	93 ,,
	No. 2	11⅛ ,,	10¼ ,,	141 ,,	156 ,,

Forty gallons of mixture were sprayed using the two kinds of nozzles and at different pressures and the time taken to pump out the mixture was noted down, from which the discharge per minute for each hose was calculated. The figures obtained for each kind of sprayer seems to be almost similar. The discharge of liquid at a given pressure is proportionate to the size of nozzles. At 120 lbs., nozzles with No. 2 disc have ejected nearly 75 per cent more mixture than with No. 1 disc. Again the increase of pressure to 150 lbs. has also resulted in extra quantity naturally thrown out.

Whatever may be the output of a machine, the real factor for the area covered in a day always depends upon the condition of coffee bushes themselves. Large bushes with plenty of foliage and growth require more mixture to be thoroughly covered than weak and poor ones. Hence, when the coffee is poor, not only less mixture is needed for each plant but also greater area can be covered

in a day as the amount of time taken to spray each plant is proportionately less. The figures given by us for the output of work per day are based on the data obtained on the Coffee Experiment Station. On the basis of 400 gallons of mixture per acre, one acre of coffee can be sprayed per day with eight two-gallons hand sprayers. With the D. S. P. pump with two lines of hose an area of $1\frac{1}{4}$ to $1\frac{1}{2}$ acres can be covered per day; with the one adapted to take four lines of hose, nearly $2\frac{1}{2}$ to 3 acres can be sprayed. The Vermorel Headland Sprayer using No. 1 nozzle, and the same amount of labour as employed to work a D. S. P. sprayer, has been found to give an output of 320 gallons of mixture per day or approximately $\frac{3}{4}$ of an acre can be sprayed. The Holder Power sprayer with four lines of hose, as originally designed can do about $2\frac{1}{2}$ to 3 acres per day. Since the machine has enough reserve power to take two more hoses, one planter has recently adapted it to take two extra lines of hose. The following figures are kindly furnished by the planter: 52 acres have been sprayed in 19 days, using 716 barrels of mixture: that is to say the sprayer has done $2\frac{3}{4}$ acres per day using 540 gallons of mixture per acre. The highest number of barrels for a single day is shown as 42, the lowest 21 barrels. The coffee is very thick and hence the small acreage done for a day. The highest number of acres done in any single day is furnished as three acres.

The new Drake and Fletcher Power sprayer has not been as yet sufficiently tested to enable us to say definitely what its capacity is. It has however been found to be capable of doing $3\frac{1}{2}$ to 4 acres or even more in a day.

The data given above can only be regarded as tentative. Figures furnished by planters owning Power sprayers go to show that the area sprayed varies from three to five acres per day.

From what has been said above, it is evident that, an increased output of the mixture by a Power sprayer working at a high pressure, does not necessarily mean an increase of acreage covered, as the labourer cannot quicken his rate of work. For practical purposes, a pressure of 120 lbs. per square inch with a D. S. P. pump, and about 150 lbs. per square inch with a Power sprayer seems to answer the purpose. Very high pressure is not only uneconomical but may prove disastrous to many makes of hose.

Nozzles.

The types of nozzles that are at present being supplied with the sprayers, leave much to be desired. For coffee spraying the most suitable type of nozzle is one which gives a fine misty wide angle spray, as then a uniform spray cover on the leaf is assured. Nozzles which give out a coarse spray, not only drench the leaves but waste more mixture than is necessary. Three types of nozzles (Fig. 11) are at present in use in coffee spraying, *viz.*, the nozzle supplied with the Holder two-gallons sprayer, the "Eichel" type used with Holder Power sprayer, and the D. S. P. nozzle. All the three types are fairly satisfactory. The D. S. P. nozzle has arrangements for adjusting the angle of the spray.

It has four separable discs No. 0, 1, 2, 3 which are screwed in position by means of the nozzle cap. The type of spray and rate of discharge are regulated by the size of the hole in the centre of the disc. It will be seen from Table 20, that the rate of discharge is greater with disc No. 2 than with disc No. 1. In the course of spraying the size of the hole in disc No. 1 gradually increases owing to the wearing action of the spray, and approximates to that of No. 2. The chief defect in most of the nozzles we are getting at present is their rapid wear, resulting in the widening of the hole in the jet. This naturally leads to a waste of the mixture, and a coarse spray. The pressure at which the mixture is pumped, *viz.*, 150 lbs. per square inch, combined with the corrosive action of the fine particles of sand contained in much of the lime used, hastens the wear on the nozzles, which are generally made of soft metal. One planter in Coorg adopted the ingenious device of replacing the centre of an Eichel nozzle with an iron piece and drilling a small hole, and claimed that the life of the nozzle was prolonged for some time. A similar device has been provided by Messrs. Holder for nozzles used with their Knapsack sprayers.

A simple type of nozzle made entirely of steel, instead of steel centered bronze ones is likely to prove satisfactory and economical. The D. S. P. nozzles have been found to be quite satisfactory, in so far as they give a fine wide angle spray. These nozzles however do not last even one season, and cost about Rs. 9. In the field, they very often develop a leak, and attempts by the labourer to set it right, often results in the altering of the angle of the

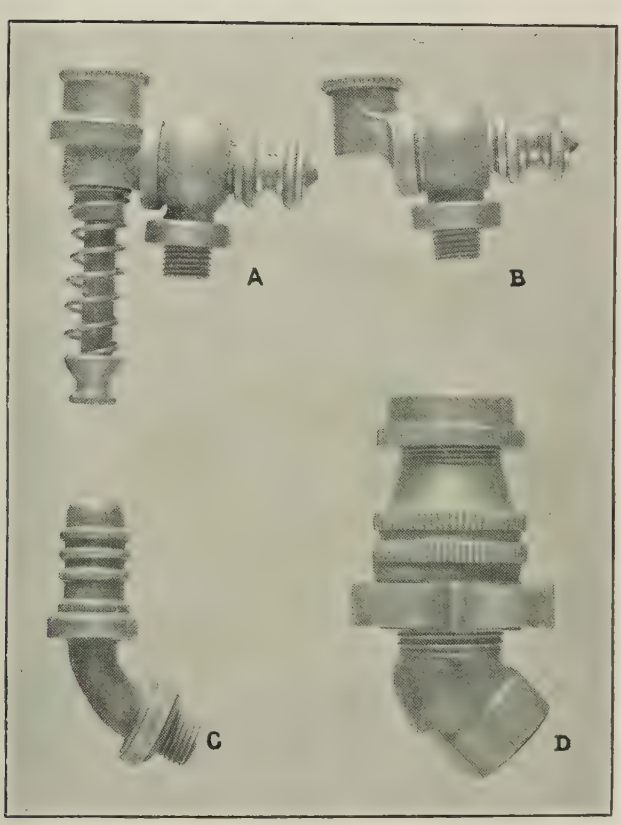


FIG. 11.

Different types of nozzles used in coffee spraying. A. Holder nozzle (Blitz) with cleaning needle. B. Holder nozzle (Sparer) A and B supplied with Holder two-gallon sprayers. C. Holder nozzle (Eichel) supplied with Holder Power sprayers. D. D. S. P. "Mistifier junior" nozzle, with lock-nut for adjusting the angle of the spray.

nozzle. In the experience of some of the planters, the nozzles supplied with the two-gallons Holder sprayers are the best ones to use, considering their cheapness and efficiency. The importance of evolving a suitable type of nozzle which will withstand the wear is being urged on the manufacturers by the Department of Agriculture in Mysore.

Hose.

The investment on hose is a fairly heavy item of expenditure as its life can be put down at two or two and a half years where high pressure hose is used and spraying is done in both pre-and post-monsoon. The brands of hose, originally supplied with Drake and Fletcher sprayers have not been found to withstand working pressure. Hose tested to withstand a working pressure of 250 lbs. and a bursting pressure of 500 lbs. or over per square inch seems to be well adapted for coffee spraying. Hoses of ½" and 3/8" diameter are used but the latter seems just as suitable as the former and is not only cheaper, but also less bulky to carry into coffee. The length of the hose required for each connection cannot be definitely laid down as it will depend upon the lie of the land and the number of trees in a row between two roads. In the case of D. S. P. pumps, lengths of more than 300 feet are not advisable as the strain on the pumping coolies is likely to be too great owing to friction in the hose. In ordinary estate practice 200-300 feet length of hose have been found to be suitable.

It has been noted that a certain length of hose goes unutilised in working hose types of sprayers. For instance, if a Power sprayer with six lines of hose is used to spray 12 rows of coffee, the length of hose from the pump to where the row begins, is not utilised for spraying, but is useful only in leading the mixture. It has been computed that nearly 30-40 feet of hose is thus wasted. A certain amount of saving can be effected by using a length of 60-70 feet of galvanised pipes, with outlets at intervals of five feet for hose connections. These pipes should be connected to the discharge end of the pump. Probably the light steel piping now available should be used even more satisfactorily than galvanised pipe and it is proposed to carry out experiments in this connection.

A thorough cleaning of the hose every day after use adds to its life. During the off season hose should be stored in a cool place, well protected with gunnies.

TABLE 21.—*Giving Data on the Working Cost of*

D. S. P. Power Sprayer 6 hoses 3½ to 4 acres per day						Holder Power Sprayer 4 hoses 2½ to 3 acres per day					
				Rs.	a.	p.				Rs.	a.	p.
Capital Investment—							Captial Investment—					
Machine ...	1,300	0	0				Machine	1,180	0	0		
Rubber hose 1,200 ft. at 6 annas ...	450	0	0				Rubber hose 800 ft. at 6 annas	300	0	0		
Barrels 12 at Rs. 6 ...	72	0	0				Barrels 12 at Rs. 6	72	0	0		
Total ...	1,822	0	0	1,822	0	0	Total ...	1,552	0	0	1,552	0	0
Depreciation charges per acre—							Depreciation charges per acre—					
1. Life of machine 10 years or 20 seasons ...	0	4	4				1. Life of machine 10 years or 20 seasons	0	5	3		
2. Rubber hose 4-5 seasons ...	0	6	0				2. Rubber hose 4-5 seasons	0	5	4		
3. Barrels 6 seasons ...	0	0	10				3. Barrels 6 seasons	0	1	1		
Total ...	0	11	2	0	11	2	Total ...	0	11	8	0	11	8
II. Interest on capital—							Interest on capital—					
Investment at 6 per cent...				0	3	8	Investment at 6 per cent...				0	4	1
III. Cost of spraying per acre including commission, labour, maistry and machine working				2	2	0	Cost of spraying per acre including commission, labour, maistry and machine working ...				2	10	0
IV. Sundries such as filter cloth, empty tins for carrying water, etc. ...				0	1	6	Sundries such as filter cloth, empty tins for carrying water, etc. ...				0	1	6
Total ...				3	2	4	Total ...				3	11	3
Or ...				3	2	0	Or ...				3	11	0

N. B.—Labour charges for transporting

Different Sprayers per acre excluding Spray material.

D. S. P. Headland pump with 2 hoses 1¼ to 1⅔ acres per day			D. S. P. Headland pump with 4 hoses 2½ to 3 acres per day			8 Two gallon sprayers 1 acre per day		
	Rs. a. p.			Rs. a. p.			Rs. a. p.	
Capital Investment—			Capital Investment			Capital Investment—		
Machine	330 0 0		Machine	330 0 0		Machine	280 0 0	
Rubber hose 400 ft. at 6 annas	150 0 0		Rubber hose 800 ft. at 6 annas	300 0 0		Barrels 4 at Rs. 6	24 0 0	
Barrels 5 at Rs. 6	30 0 0		Barrels 8 at Rs. 6	48 0 0				
Total ...	510 0 0	510 0 0	Tatal ...	678 0 0	678 0 0		304 0 0	304 0 0
Depreciation charges per acre—			Depreciation charges per acre—			Depreciation charges per acre—		
1. Life of machine 10 years or 20 sesaons	0 3 6		1, Life of machine 10 years or 20 seasons	0 1 9		1. Life of machine 14 years or 28 seasons	0 2 8	
2. Rubber hose 4-5 seasons	C 6 5		2. Rubber hose 4-5 seasons	0 6 5		2. Barrels 6 Seasons	0 0 10	
3. Barrels 6 seasons	0 1 1		3. Barrels 6 seasons	0 0 10				
Total ...	0 11 0	0 11 0	Total ...	0 9 0	0 9 0		0 3 6	0 3 6
Interest on capital—			Interest on capital—			Interest on capital—		
Investment at 6 per cent ...	0 3 3		Investment at 6 per cent ...	0 2 2		Investment at 6 per cent.		0 2 4
Cost of spraying per acre including commission, labour, maistry and machine working ...	2 7 0		Cost of spraying per acre including commission, labour, maistry and machine working ...	2 4 0		Cost of spraying per acre including commission, labour, maistry and machine, working.		4 3 6
Sundries such as filter cloth, empty tins for carrying water, etc.	0 1 6		Sundries such as filter cloth, empty tins for carrying water, etc.	0 1 6		Sundries such as filter cloth, empty tins for carrying water, etc. ...		0 1 6
Total ...	3 6 9		Total ...	3 0 6		Total ...		4 10 10
Or ...	3 7 0		Or ..	3 1 0		Or ...		4 11 0

water not included.

It will be seen from the above table that the working cost of Holder Power sprayer is higher than that of the Drake and Fletcher Power sprayer. The former consumes 2 gallons petrol and about 45 ozs. of lubricating oil, the latter nearly 1 gallon of petrol and 4 ozs. of oil for spraying, 1,500 gallons of mixture. While the working costs of the D. S. P. pumps compare favourably with those of Power sprayers, it should be noted that the working of D. S. P. pumps with four lines of hoses is slightly cheaper than that of the one with two lines of hoses. In calculating the depreciation charges, it must be admitted, however that, since Power sprayers have not been long in the field, the figures given on the "life of the machine" should be taken as approximate.

Progress of Spraying in Mysore

In conclusion, a word may be said about the progress of spraying work in Mysore. From small beginnings in 1922, which consisted mainly of demonstrations on a small scale, the spraying work has progressed to such an extent that during 1932, an area of 18,000-20,000 acres have been sprayed in Mysore. Figures for areas outside Mysore are not available, but there is no doubt whatever that in these areas also a fairly rapid expansion of the sprayed areas is taking place.

Summary.

In this bulletin, the importance of spraying in the control of coffee diseases such as Black Rot, Leaf Disease, Die Back and to a certain extent in the control of Coffee Borer, is pointed out.

Based on the nature of attack and time of appearance of the diseases, experiments have been carried out with special reference to Leaf Disease, to find out the right time of spraying and the optimum strength of mixture.

Different spray mixtures have been tried, and their efficacy in minimising percentage infection tested, with the result that 0·5 per cent Bordeaux mixture has been found to be the cheapest and safest mixture to use.

Spreaders, added to Bordeaux mixture, such as resin soda, lime-caseinate and linseed oil, have been tested with regard to their effect on the physical properties of the mixture, their efficacy in warding off the disease, and their influence on copper retention on sprayed leaves. It

is concluded that Bordeaux mixture with lime-caseinate, though not the best, is the most suitable one to use at present.

The use of Bordeaux mixture is preferred to that of Burgundy mixture, judging from efficacy against Leaf Disease and crop yield.

Increase in crop yield due to spraying is indicated by figures furnished by coffee planters in Mysore, Nilgiris and Shevaroys.

Considerable attention has been devoted to spraying machinery, some of which have been already in use, and others of which are newly being tried, and their advantages and disadvantages have been discussed. Attention is drawn to the fact that by a simple device, the D. S. P. sprayer can be fitted with four lines of hose, instead of as ordinarily, with only two.

We wish to acknowledge our indebtedness to Dr. Leslie C. Coleman, Director of Agriculture in Mysore, for valuable suggestions given to us in the course of the work.

Literature cited.

1. Anstead R. D. Spraying of Coffee. Planters' Chron. XVI, 1921, 670-673.

2. Ashplant, H: The Spraying of Rubber: Circulars of the Rubber Specialist, No. 1. Planters' Chron. XXI, 1926, 270-272.

3. Barker, B. T. P. and C. T. Gimingham: The Fungicidal Action of Bordeaux mixtures. Jour. Agr. Sci. IV. 1911, 76-94.

4. Bedford, Duke of, and S. U. Pickering : Science and Fruit growing, London, 1919.

5. Burck, W: Over de koffiebladziekte en de middelen om haar te bestrijden. Mededeelingen van 's Lands Plantentuin IVenV, 1887, and 1889.

6. Butler, O: Bordeaux Mixture: I. Physico-Chemical Studies. Phytopath. 4, 1914, 125-180.

7. Coleman, L. C: Diseases of the Areca Palm. I. Koleroga. Dept. Agr. Mysore State, Mycological Section. Bul. 2, 1910.

8. Coleman, L. C: Spraying for leaf disease in Coffee: Jour. Mys. Agri. and Exp. Union, II 1920, 77-79. See also Planters' Chron. XV. 1920, 529-530.

9. Coleman, L. C., Venkata Rao, M. K. and Narasimhan, M. J. Black Rot or Koleroga of coffee in Mysore, Dept. Agr. Mysore State, Mycological Section Bul. 5, 1923.

10. Coleman, L. C: The Mysore Coffee Experiment Station. Dept. Agr. Mysore State, Coffee Exp. St. Bul. No. 1. 1930.

11. Delacroix, G: Les Maladies et les ennemis des Cafeiers 1900.

12. Frattini, G. N: Summary of experiments conducted by the Scientific Assistant for Mysore, 1917.

13. Kelhofer, W. Über die Ausführung und die Ergebnisse von Haftfestigkeitsversuchen kupferhaltiger Bekämpfungsmittel gegen die Peronospora. Zeitschr. f. Pflanzenkrankh. 17, 1907—1-12.

14. Kulisch, P: Die Darstellung haltbarer Kupferbrühen zur Bekämpfung der Peronospora. Landw. Zeitschr. f. Elsass-Lothringen, 1911, No. 17. See Rev. in Zeitschr. f. Pflanzenkrankh. 22, 1912, 301-302.

15. Kunhikannan, K: Annual Report of the Agricultural Department, Mysore. Report of the Entomologist, 1928-29, 1930, 29-36.

16. Lutman, B. F: Some Studies on Bordeaux Mixture. Vermont Agri. Exp. St. Bull. 196, 1916.

17. Martin, Hubert: The Scientific Principles of Plant Protection: Edward Arnold & Co., London, 1928.

18. Martin, Hubert: Studies upon the copper fungicides 1. The interaction of copper sulphate with calcium hydroxide: Ann. Appl. Biol. XIX, 1932, 98-120.

19. Martin, H. and E. S. Salmon—The Fungicidal Properties of certain Spray-fluids. X. Glyceride oils. Jour. Agri. Sci. Vol XXIII, 1933, 228-251.

20. Mayne, W.W: Annual Report of the Coffee Scientific Officer, 1931-32.

21. Millardet, A: and Gayon, W: Journ d' Agri, prat, 51 1887.

22. Munro, D. G. and Sundararaman, S: Coffee Spraying Experiments. Planters' Chron. XVIII, 1923, 193-196.

23. Munro, D. G. Coffee Spraying Experiments. Purchikadu, Planters' Chron. Vol. XVIII, 1923, 198-201.

24. Munro, D. G. The spraying of coffee. Planters' Chron. Vol. XXI, 1926, 826-828.

25. Munro, D. G. Spraying Experiments in coffee with various types of pumps. Planters' Chron. XXII, 1927, 368-372.

26. Narasimhan, M. J: Casein as an adhesive in Spraying against Areca Koleroga. Jour. Mys. Agri. and Exp. Union V. 1923, 26-29.

27. Narasimhan, M. J: A new spray mixture against Areca Koleroga. Mys. Agri. Calendar. 1928, 24-25.

28. Narasimhan, M. J: Linseed oil as an adhesive for Bordeaux Mixture. Jour. Mys. Agri. and Exp. Union, X, 1929, 145-146.

29. Narasinga Rao, T: Spraying against Black Rot of Coffee, Jour. Mys. Agri. and Exp. Union, V, 1923, 220-224 and VI, 1924, 190-192.

See also Planters' Chron. XX, 1925, 251-253.

30. Neuweiler, E: Kartoffelspritzversuche, 1916-1925 Abst. Rev. Appl. Mycol. 6. 1927, 48-50.

31. Newton, W, Johnston, F. B. and Yarwood, C: Factors influencing the Character of Bordeaux mixture, Proc. Canadian Phytopath. Soc. 1930. 21-26.

32. Pickering, S. U: Jour. Chem. Soc. 91, 1907.

33. Ruhland, W. Zur Kenntnis der Wirkung des unlöslichen basischen Kupfers auf Pflanzen mit Rücksicht auf die sogennante Bordeauxbrühe. Arb. Biol. Abt. f. Land-u-Forstw. 4, 1904, 157-200.

34. Schaffnit, E. Eiweisserdalkaliverbindungen als Zusatzstoffe für Bekämpfungsmittel zur Erhöhung des Haftvermögens. Zeitschr. f. Pflanzenkrankh. Bd. 31, 1921, 19-22.

35. Schmidt, E. W: Wie kommt die Wirkung der Kupferkalkbrühe zustande? Centralbl. f. Bakt. Abt. II 61, 1924, 356-367.

36. Sundararaman, S: Note on inspection of sprayed plots in Purchikadu and Karakadu, Coorg. Planters' Chron. XVIII, 1923, 585.

37. Travers-Drapes. E. H. A: District Notes, Shevaroys Planters' Chron. XXI 1926, 548-549, and 666-670.

38. Windle, E. G: Modern Coffee Planting. 1930.

WD 26—GPB—1,500—26-8-33.